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DECEMBER 1960 VOLUME 3 NUMBER 30 MONTHLY 3/6

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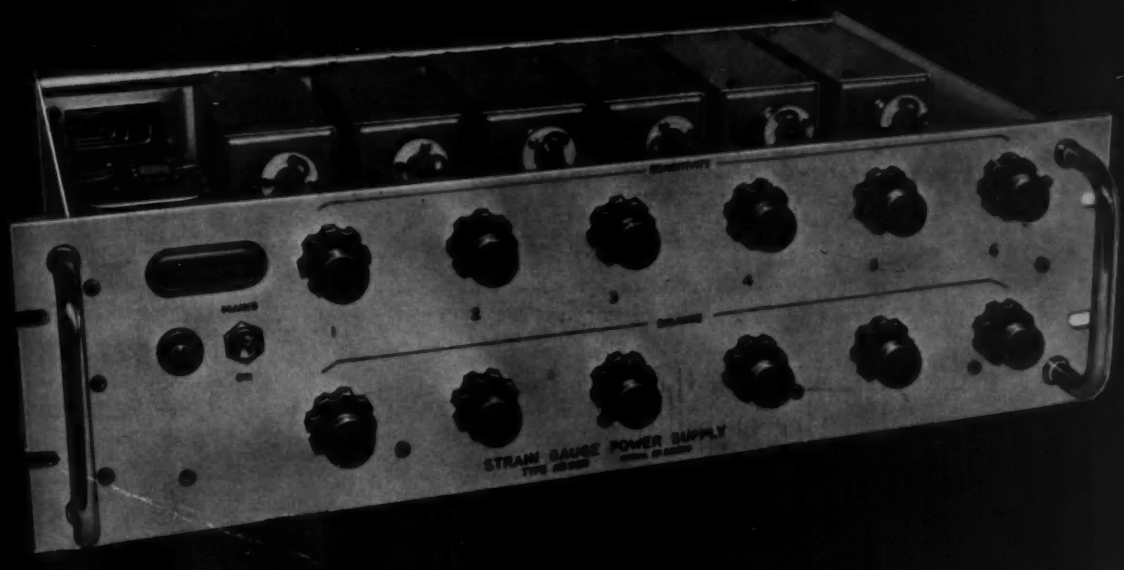

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VOL 3 NO 30 DECEMBER 1960

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LOOKING FOR A JOB? Control *carries the best jobs going in instrument and control engineering.* **SEE PAGE 200 AND ONWARDS**

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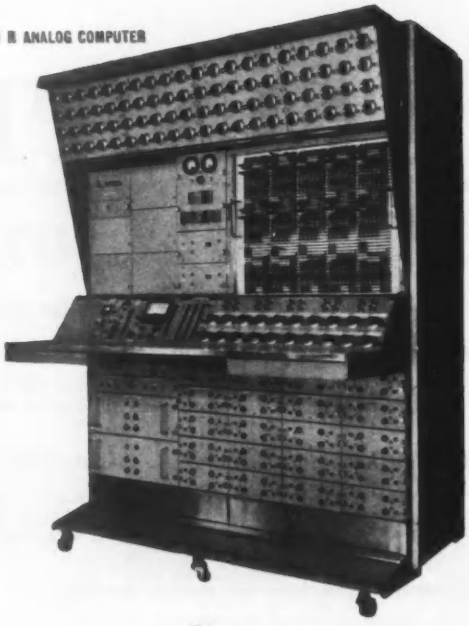

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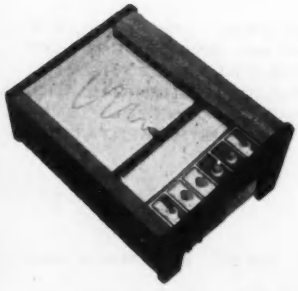

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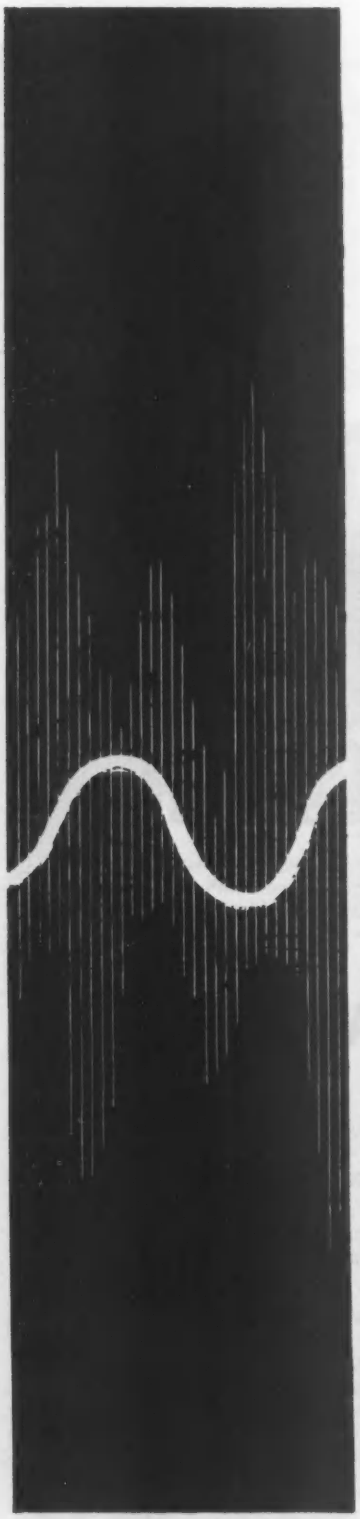

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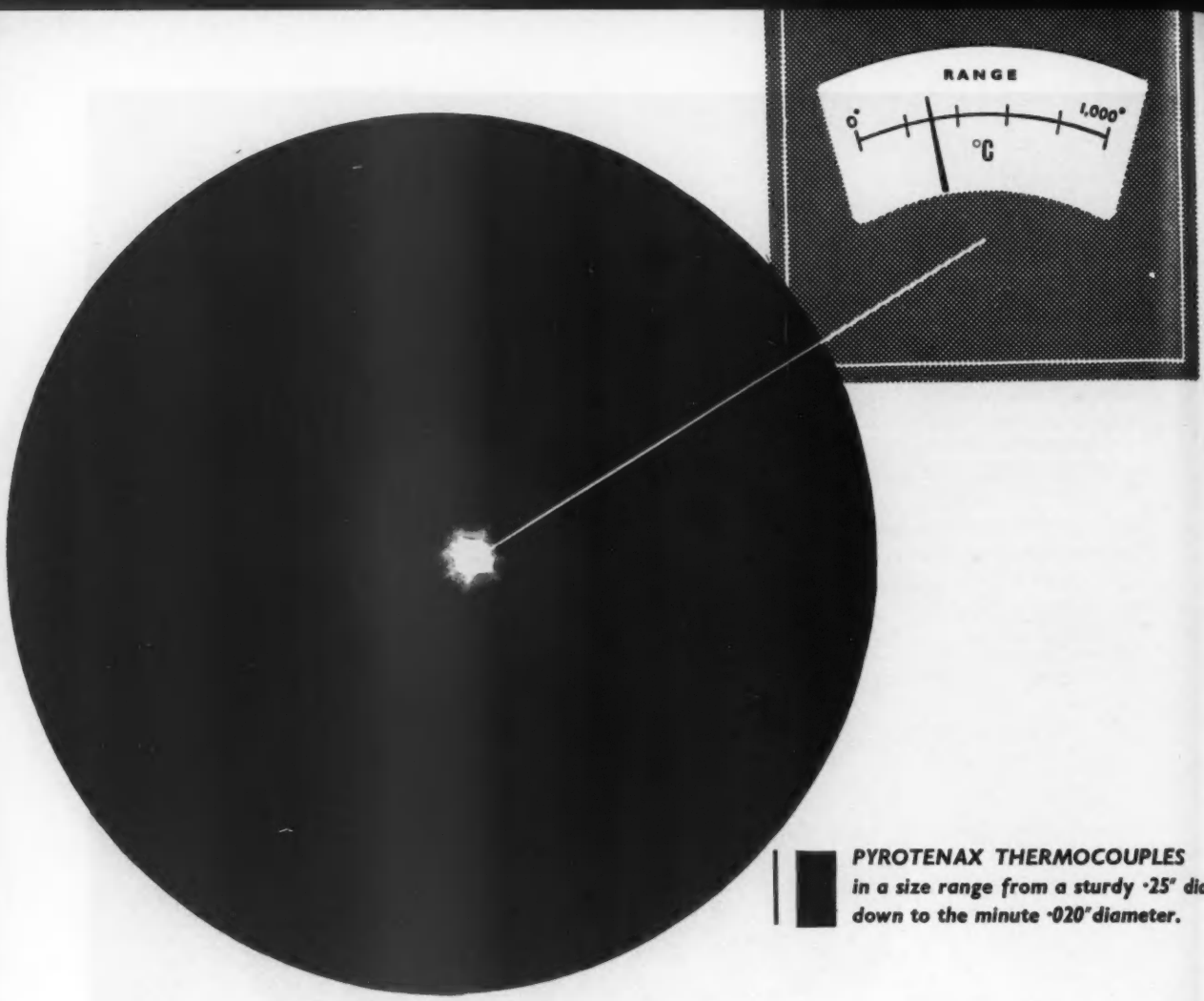

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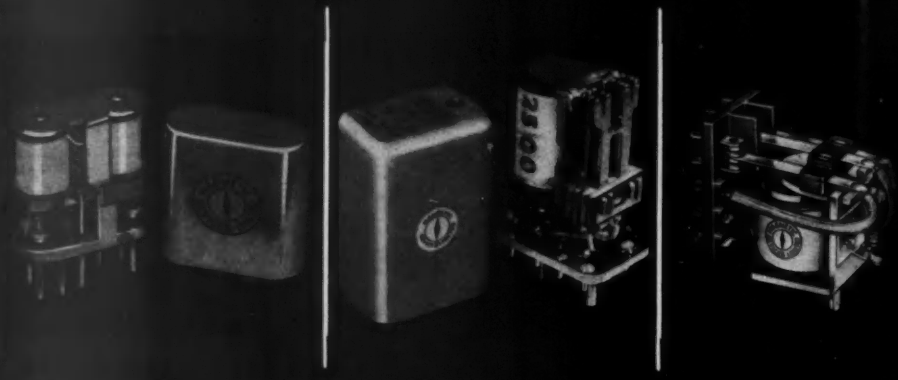
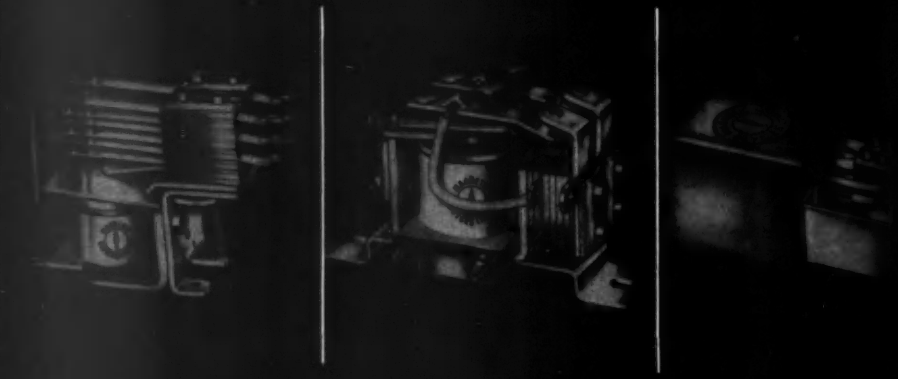
320 325	9,200	440 250	5.6 VA 1.8 watts	10 amps. at 30v. D.C.



Relay	Max. D.C. Coil resistance	Max. Op. Voltage	Coil Loading	Max. Contact Rating
285	12,500	250	3.6 watts (max.)	6 amps.
2400	14,000	240	0.16–4 watts	5 amps.
305	40,000	250	80 milliwatts to 6 watts	8 amps.

Relay	Max. D.C. Coil resistance	Max. Op. Voltage	Coil Loading	Max. Contact Rating
108 109	6,000 10,800	440 250	3–6 VA 1.8–3 watts	10 amps.
166 166	7,500 9,800	440 250	5–6.6 VA 2.6–3.3 watts	15 amps.
598H3	1,400	24	Independent of controlling supply	5 amps.



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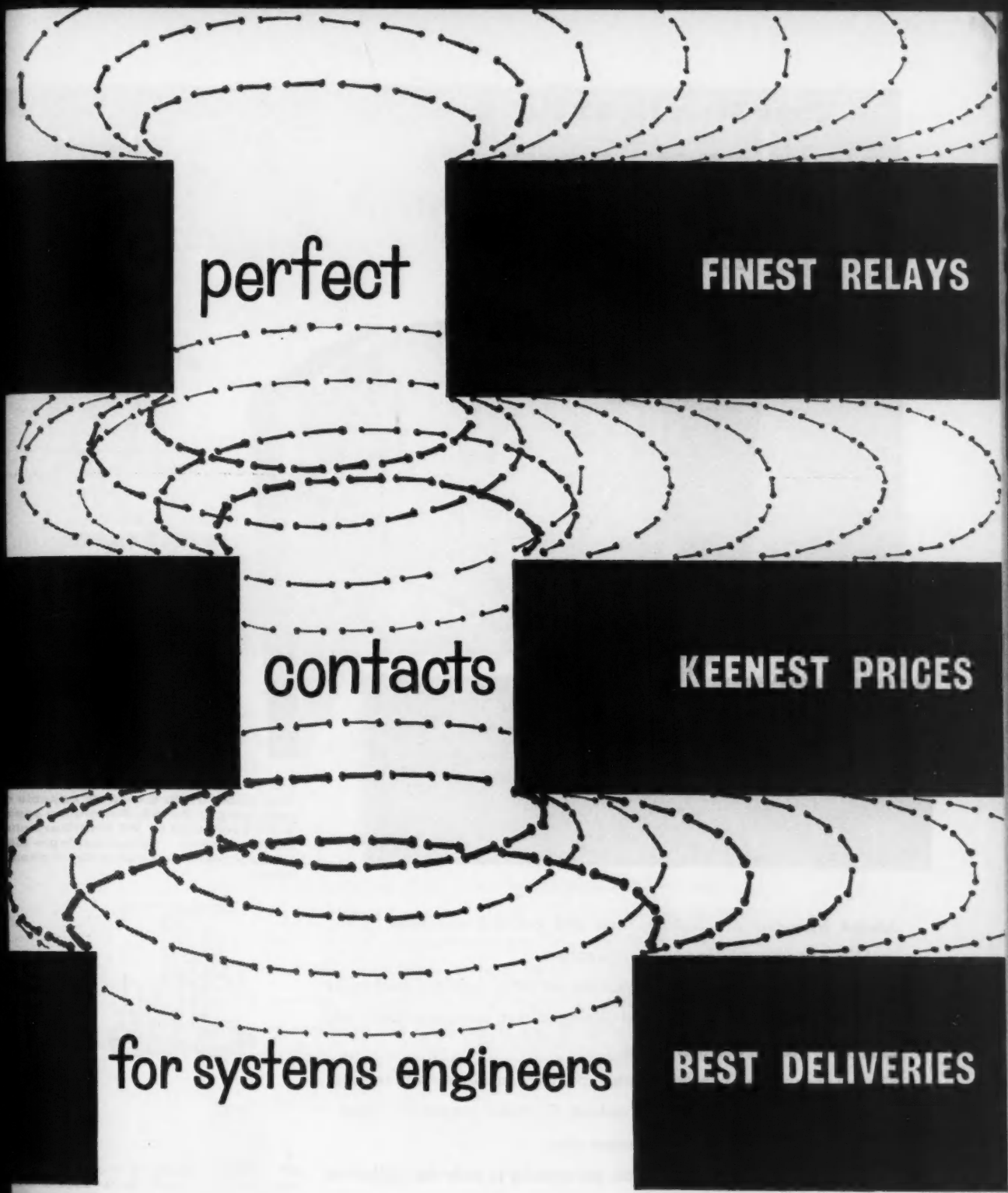

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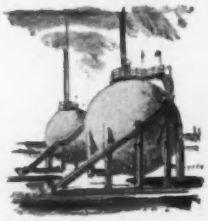

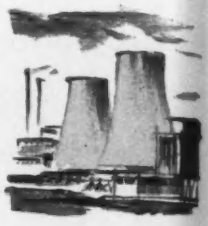

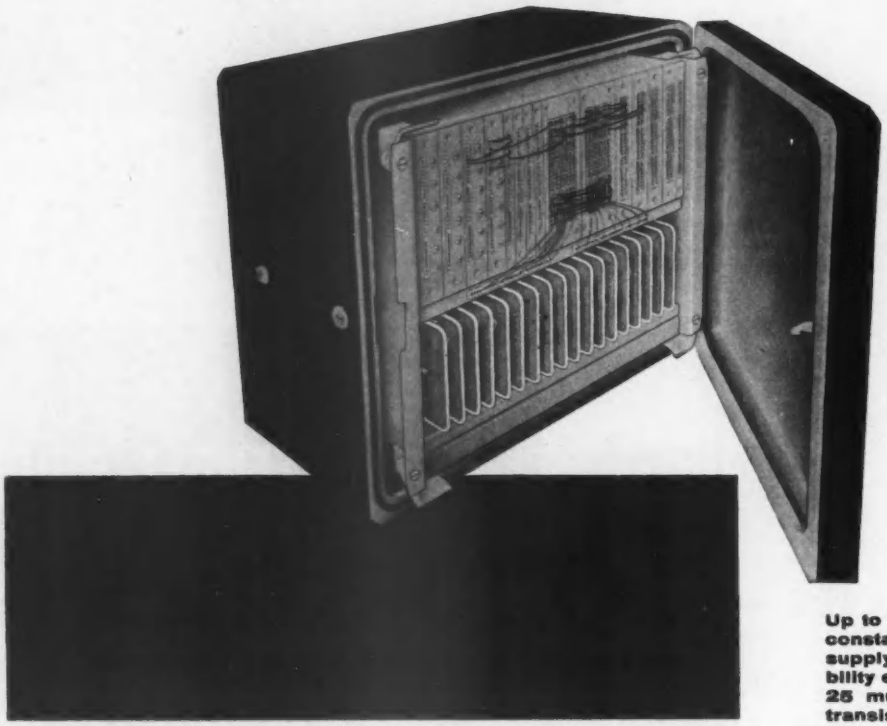

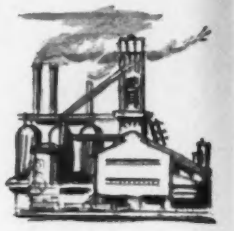

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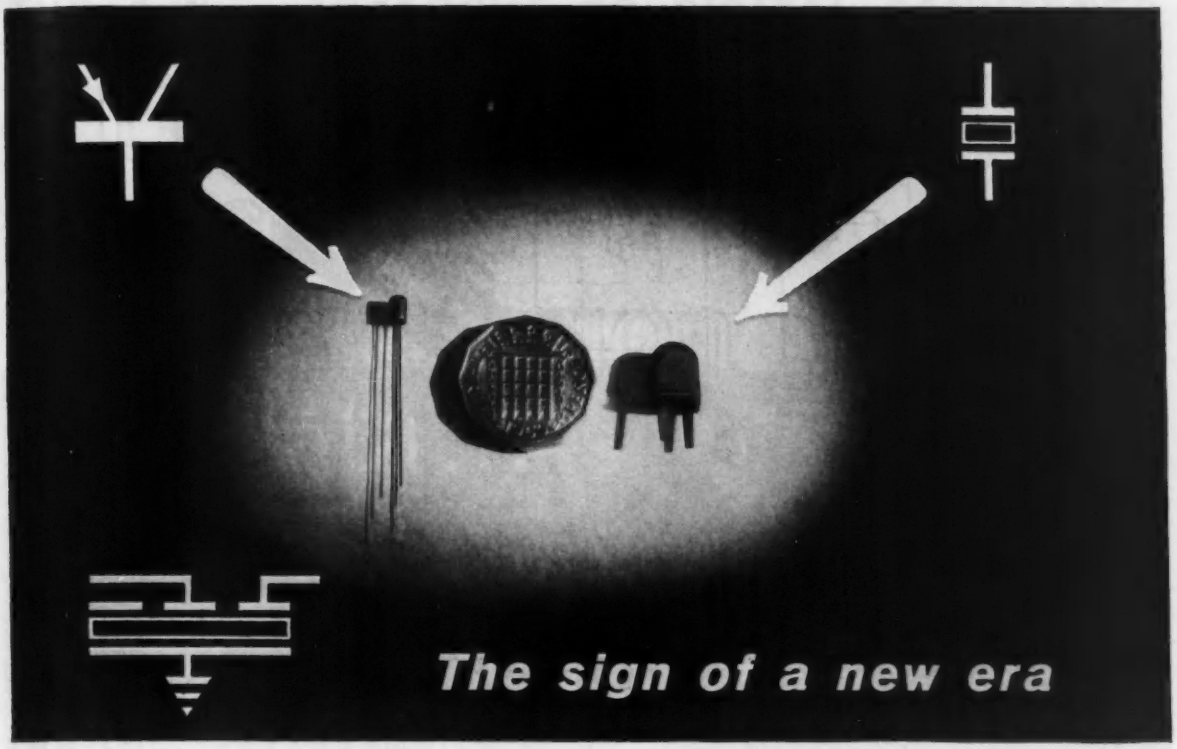

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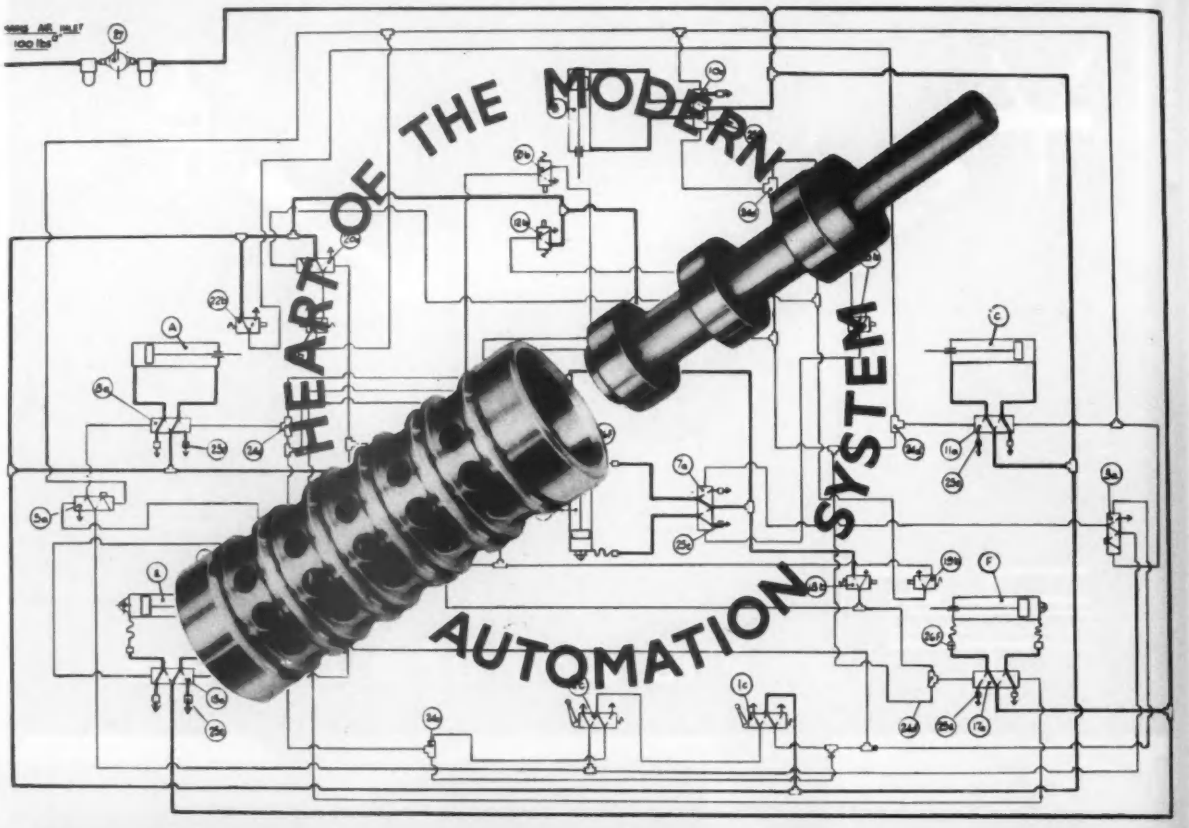

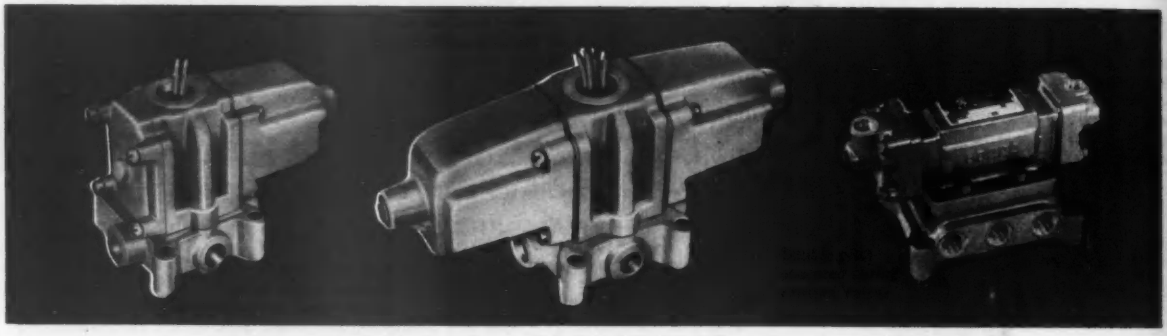

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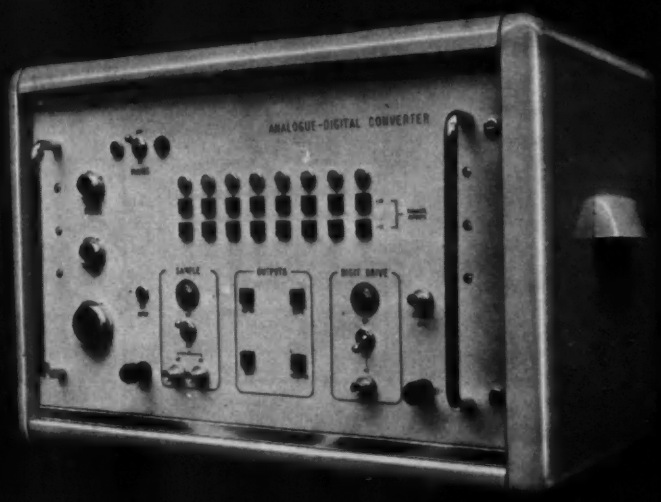

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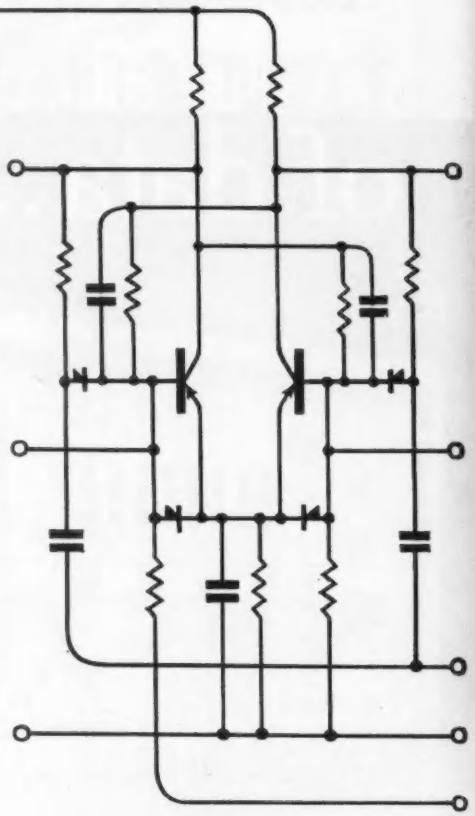

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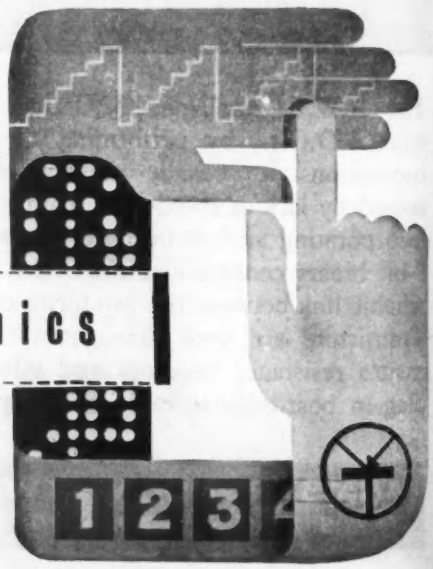

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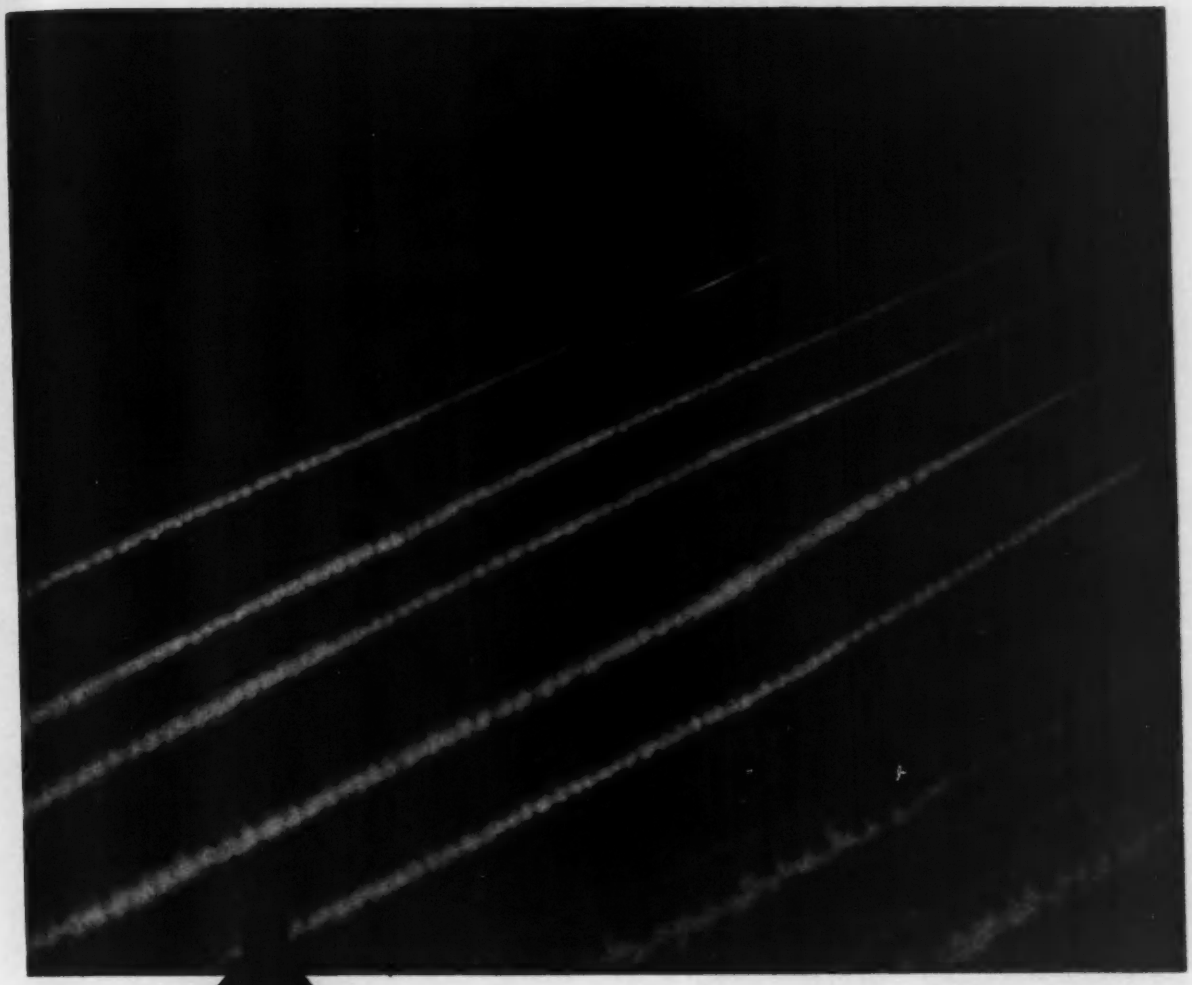

Aviation

There are few industries which, for speed of evolution and progress, can be compared with the aircraft industry. The key to this rapid growth has been research, and it is in this field that 'VSG' variable delivery hydraulic pumps and transmission gears have played an important part not only in this country but overseas.

Test rigs of various kinds both for airframe and jet engine development have incorporated 'VSG' equipment as being most suitable for giving that precise control necessary to simulate the required conditions.

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Dielectric Heating - 3

Some further details of the uses to which dielectric heating can be put are given in this data sheet, being continued from data sheet No. 11.

The Woodworking Industry

A most important development in recent years in the woodworking industry has been the introduction of synthetic resin adhesives of the thermosetting type for the bonding and adhesion of wooden components.

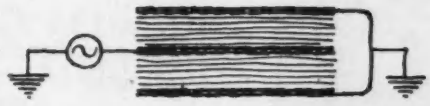
Setting of these resin adhesives proceeds at a rate largely determined by temperature. For instance, urea formaldehyde, one of the resins in common use, sets as follows:

TEMPERATURE	SETTING TIME
65°F	3 hours
80°F	1 hour
150°F	3 minutes
190°F	1 minute

The resultant bonded joint is equally satisfactory in each case. Most of the power supplied when dielectric heating is used is absorbed by the resin, the heat thus being concentrated where required and power consumption reduced to a minimum.

Plywood

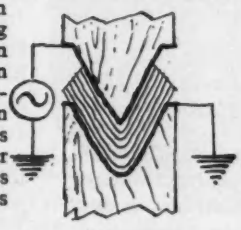
With dielectric heating consuming power only during the heating cycle, plywood can be produced with considerable savings in heating times and costs.



For example, in a press holding 100 3-ply ½" thick assemblies, the resin glue is set in 20 to 30 minutes, depending upon the dryness of the wood. An output of up to 60 cu. ft. of plywood is obtained per hour using a 25 kW H.F. generator.

Curved Laminated Sections

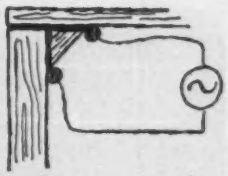
Curved laminated sections are being increasingly used in contemporary furniture, and with dielectric heating rapid production can be achieved using wooden shaping blocks in single daylight presses. An alternative method of providing heat by conduction from heated metal strips becomes increasingly slower as the total section thickness rises above 0.05 inch, as shown below:



TOTAL THICKNESS OF LAMINATIONS	*Comparative heating times in minutes* CONDUCTION	DIELECTRIC
1 inch	20	4
½ inch	5½	2½
0.6 mm veneer	1	1¼

Furniture Assembly

Because of the savings in glueing processes already instanced, dielectric heating is being extensively used in the furniture trade. It leads also to reductions in labour and floor space, with the elimination of assembly jigs. The heating equipment can be placed directly in the production line, cutting handling to a minimum.



Resin-bonded Wood Chipboard

A substitute for natural timber is made from wood waste and chippings, broken down to a coarse size, mixed with synthetic resin and heated under pressure. Dielectric heating gives quick and uniform heating, and increased fluidity reduces the power required for the final pressing and curing operation. In a continuous process, the length of the press required is also reduced.

Blockboard

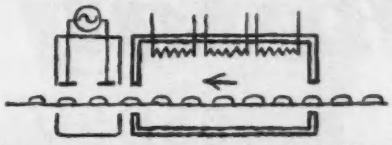
Production of blockboard by edge glueing strips of wood also provides an excellent use for dielectric heating, since considerable savings in time and labour can be effected owing to the large areas of glue line involved.

Other Resin-bonded Products

Dielectric heating is also used in the manufacture of other resin-bonded or impregnated products such as grinding wheels, impregnated woods, fabrics, felts, glass-fibre and similar products.

Foodstuffs

Increased use is being made of dielectric heating in many processes connected with foods; these include de-freezing and melting, sterilisation and disinfestation, drying of breakfast cereals, dog biscuits, rusks etc., heating of nuts to facilitate shelling and other similar types of application. Although some cooking processes are technically



possible, as for example bread baking, the 'unbrowned' product has so far proved unacceptable to the public and a completely dielectric process uneconomical. When combined with conventional baking, however, as now in the biscuit trade, where dielectric heating is being used to complete the baking of biscuits, it can produce normal biscuits in ⅓ to ¼ the usual baking time.

There are in fact so many potential applications of dielectric heating (and these applications are increasing daily as the chemical industry develops new products, as for example synthetic fibres) that the selection given in the present series of data sheets covers only a part of the whole field.

For further information get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available—"Induction and Dielectric Heating" is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity. Ask for a catalogue.

7510 A

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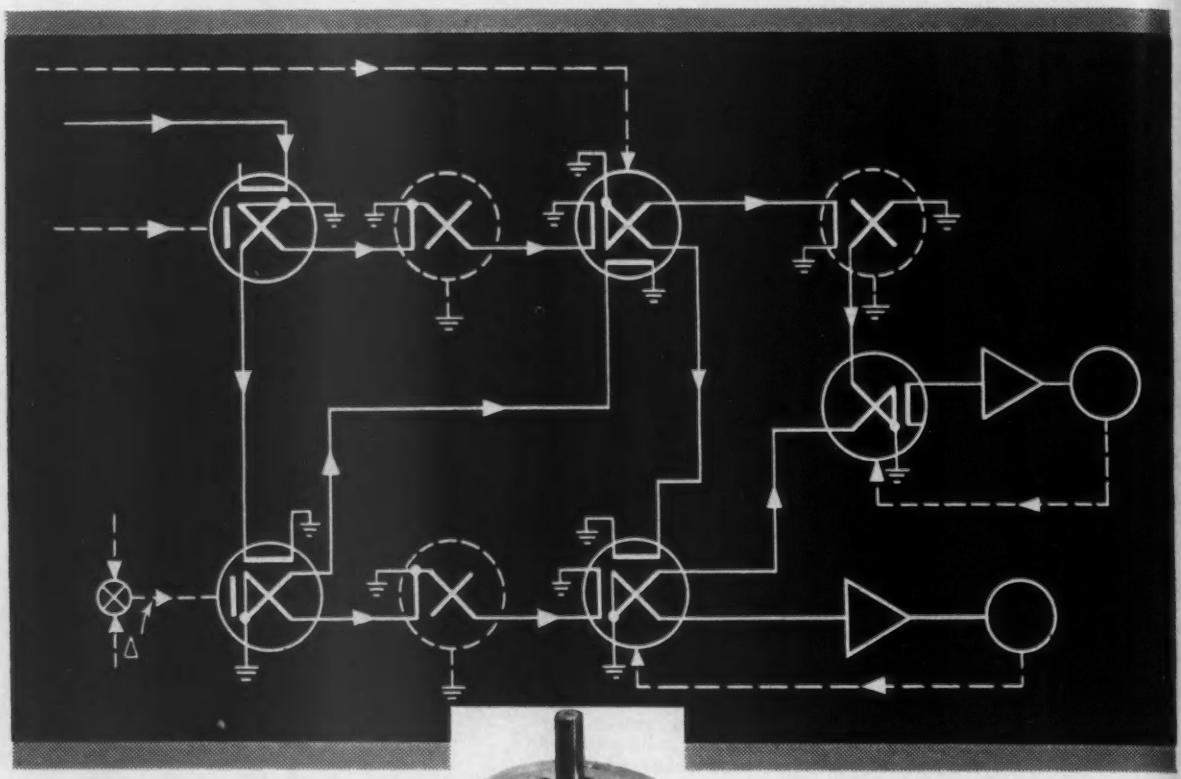

Ketay

105D2V Resolver

The 105D2V is a high precision, high impedance Size 15 Resolver with a resolution error of 0.1% and feedback or compensation windings on the stator, for application in high performance computer systems.

This Resolver (USA BU-ORD MARK 4 — MOD 1 RESOLVER) provides accurate trigonometrical functions of a given input voltage or is used to interchange rectangular and polar co-ordinates. It can also be used as an accurate Synchro in four wire data transmission systems and as a precision phase shifter.

Through-bore construction is employed and every winding is terminated at an isolated screw type terminal block thus eliminating all internal connections.

Technical specification

Number of windings	Stator . . . . . 2 Rotor . . . . . 2 Feedback . . . 2
Excitation winding	Stator
Excitation frequency	400 c/s
Voltage Rating	26/26 V
Test Voltage	15 V
Input Impedance, Nominal	480(±15%) ±j2500 (±10%)
Transformation Ratio	0.98± .01
Phase Shift	8.5° ±0.5°
Resolution Error	0.1%
Null Point Error	5 mins.
Total Null Volts	15 mV
Fundamental Null Volts	8 mV
Tuned Impedance, Nominal	10,000 ohms
D.C. Resistance (Nominal), ohms	390 Stator 320 Rotor 520 Feedback
Moment of Inertia	9.25 gm cm²
Weight	6.2 oz
Operating Temperature	−55+75°C

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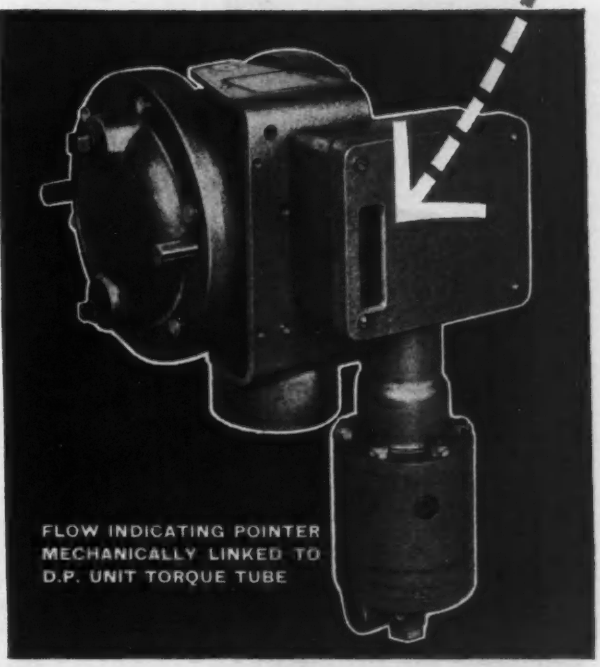
With ranges from 0-25" w.g. up to 0.40 p.s.i., static pressures up to 6,000 p.s.i., a sensitivity of 0.02% of full scale and linearity within 0.5% of full range, the AEI/Barton flow meter can out-perform any comparable instrument. *AND* list price for the instrument illustrated is from £98 (100% stainless steel body at little extra cost).



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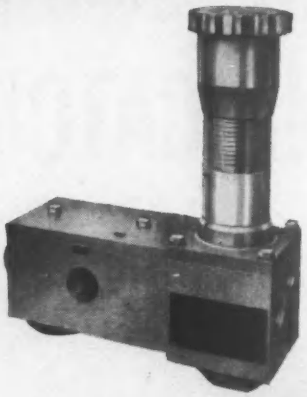
If you've a hydraulic problem



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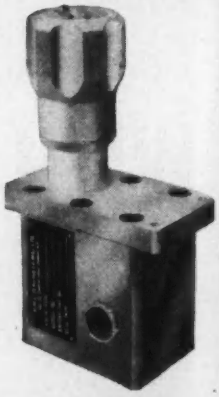

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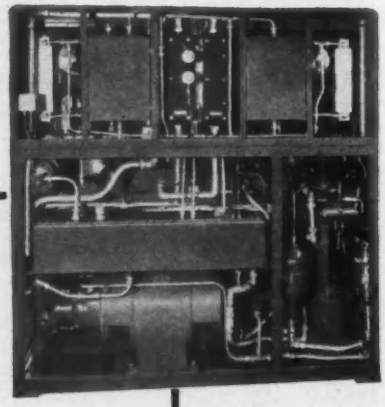

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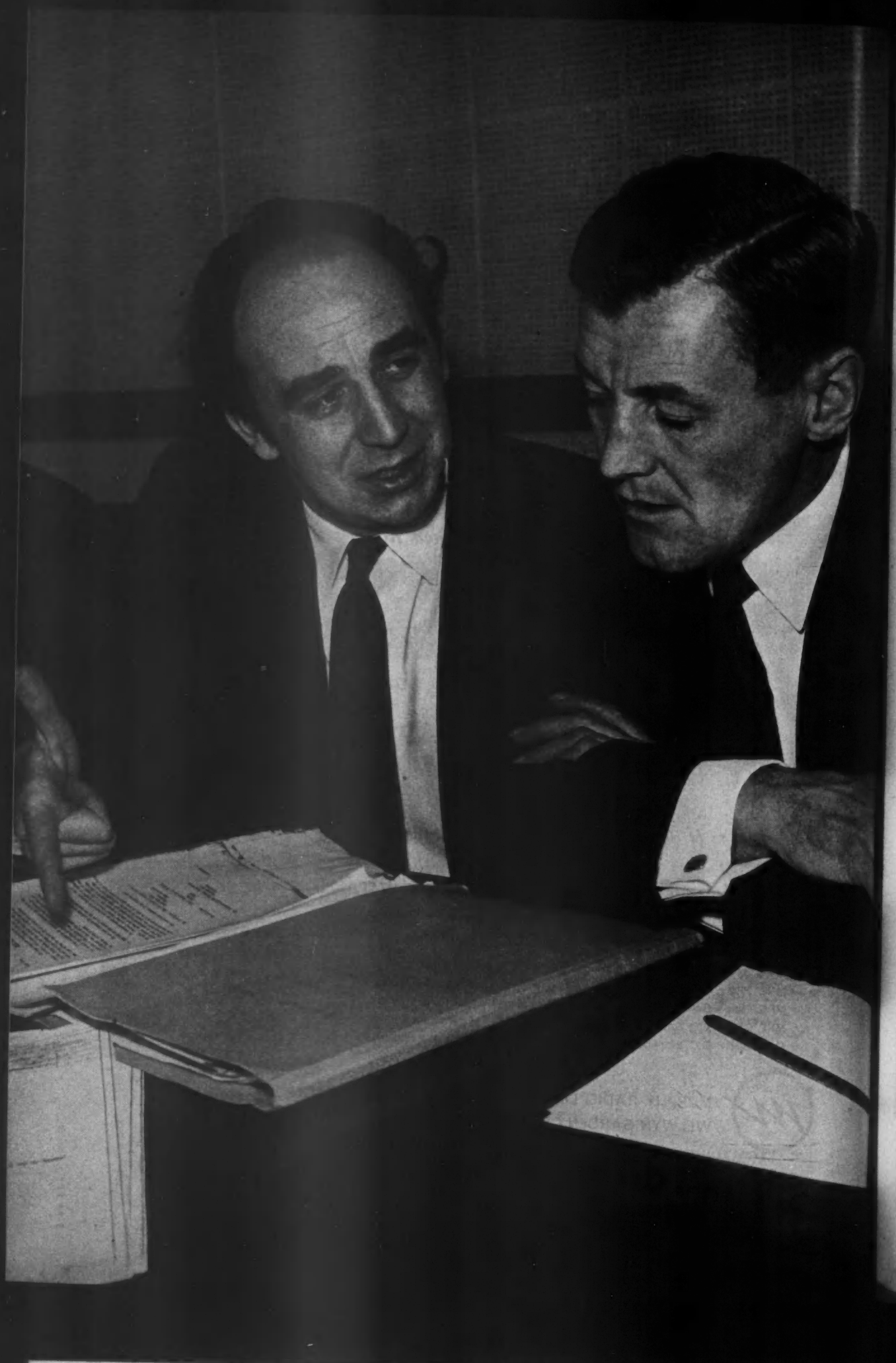

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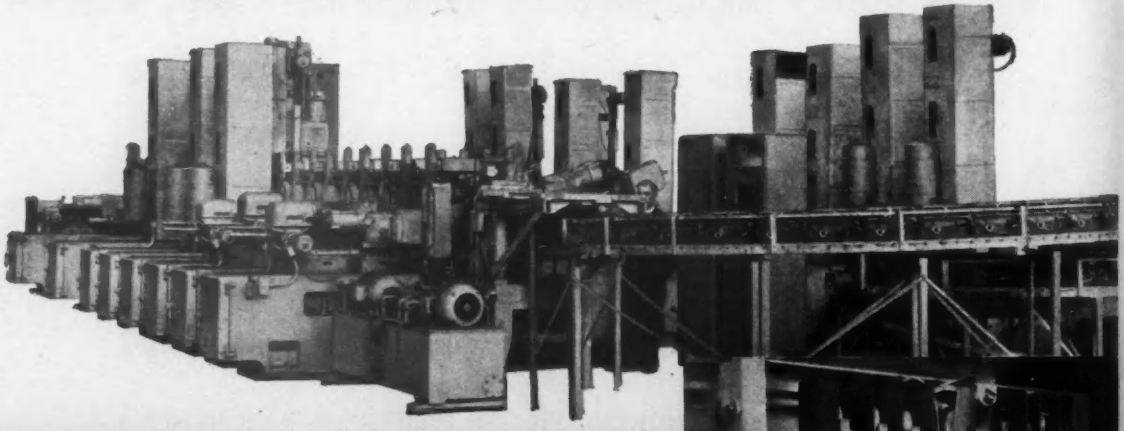

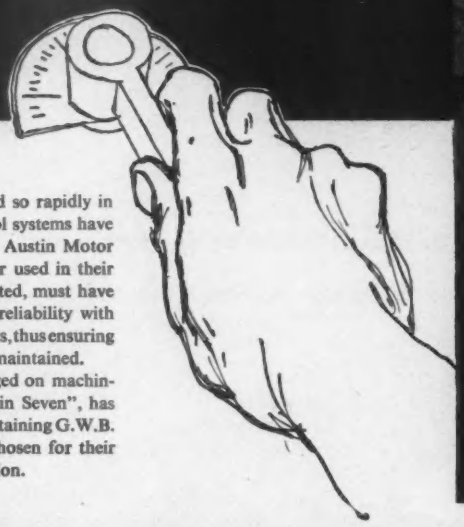

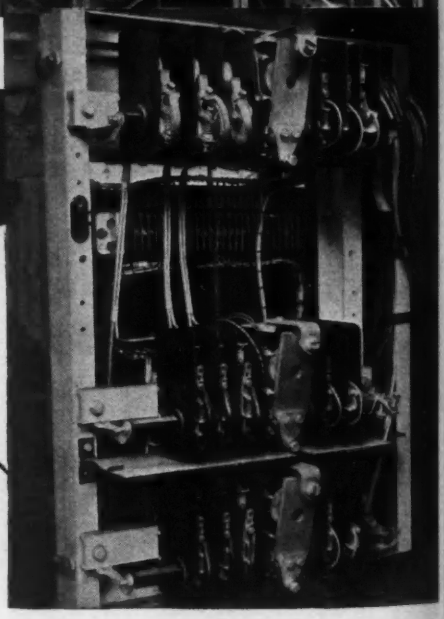

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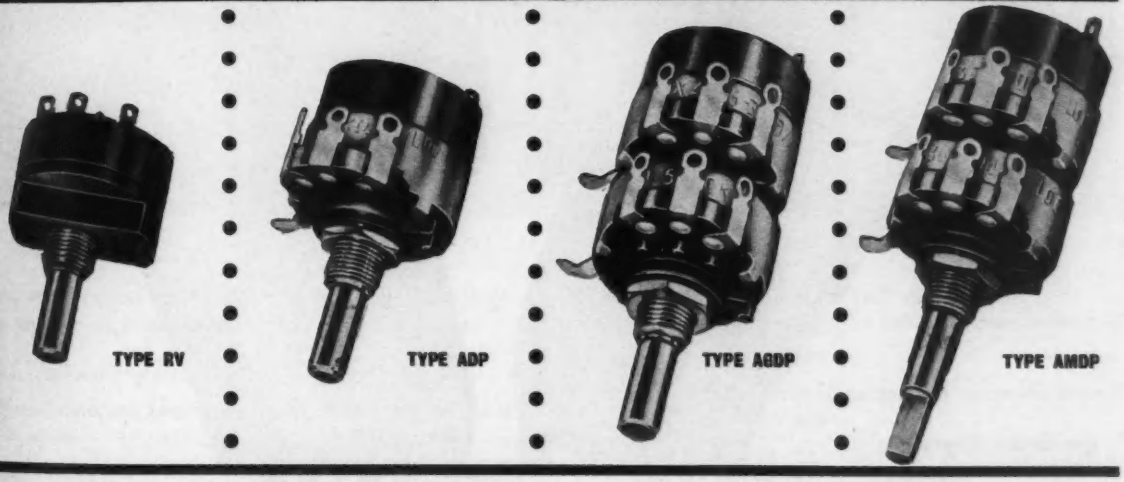

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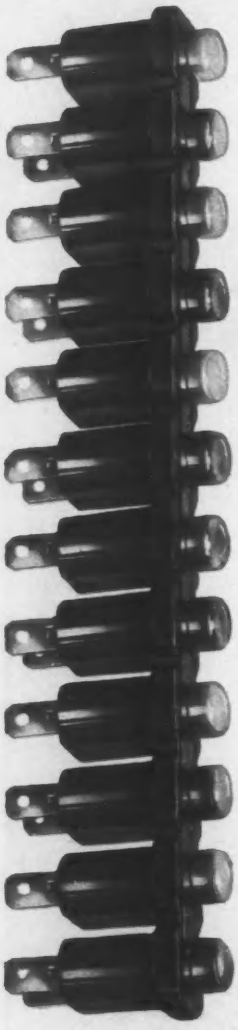

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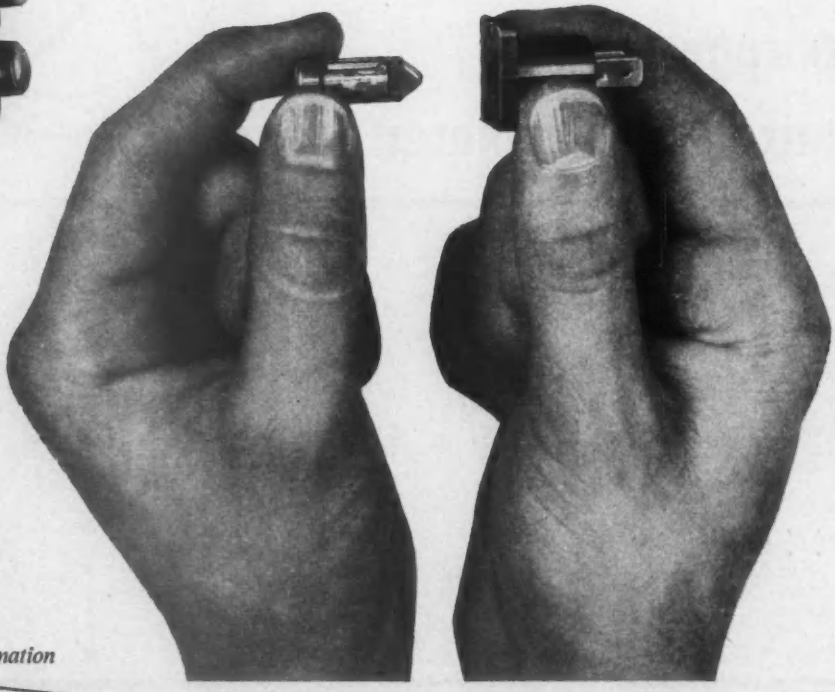

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DTV/11

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Here is a summary of information:

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  20 amps at 30V D.C. non-inductive
* **Weighs only 2¼ ounces**
* **Coils can be vacuum impregnated (to meet general M.O.D. spec. Def. 5000)**

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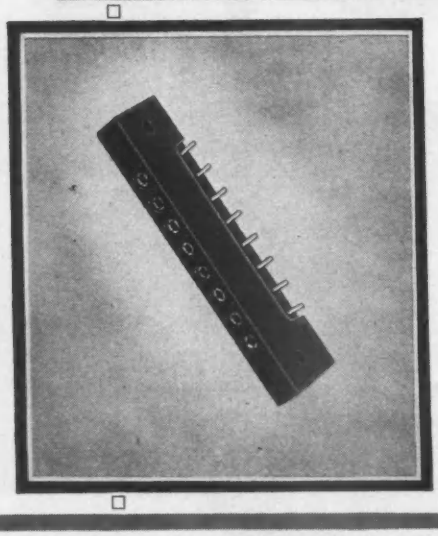
EIGHT-WAY TEST-POINT CONNECTOR



The new eight-way test-point connector is the first of a new series being made available for use with printed wiring boards. It enables test points to be conveniently located on the printed board so that measurements can be made with the board in position.

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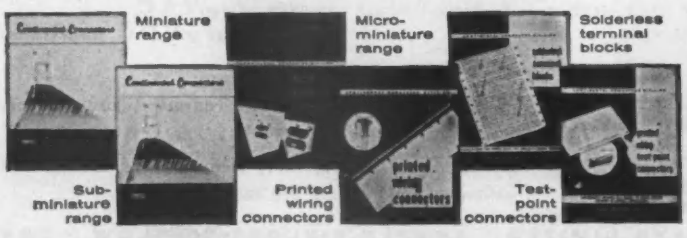

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The SA.46C is ideally suited for the generation or the measurement of delays in pulse circuits and is, in fact, the only equipment which provides, digitally, delayed output pulses derived from an internally or externally applied input In checking oscilloscope time bases, in ballistics, aerodynamics and indeed in any pulse circuit application the SA.46C is an invaluable aid in solving many measurement problems offering an accuracy of ±1 μsec.

Assembled from standard Racal plug-in units incorporating printed circuits the SA.46C is easily serviced. Write for complete specification and performance data.

Range of delays: 3 μSecs. to 999,999 μSecs., in 1 μSec. steps.
Stability: ±1 part in 10^6 with temperature controlled crystal.
Input reqd: 15V peak pulse.
Output: 15V peak pulse. Rise time: 0·2 μSecs.
Duration: 2 μSecs. Power Supplies: 200/250V, 45/65 c/s.

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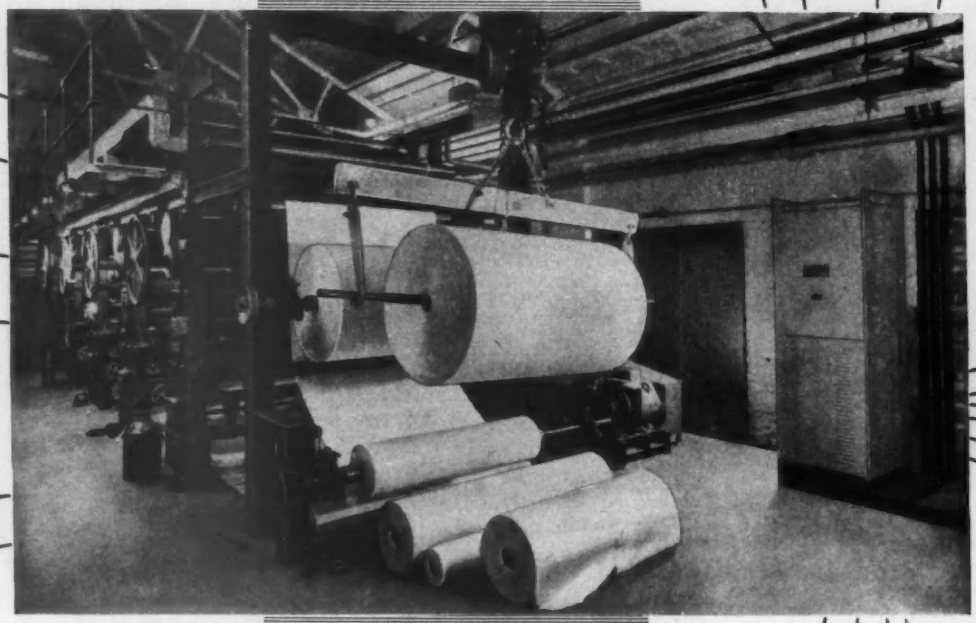
Variable Speed Drives



20 h.p. Varimag Drive installed on a proofing machine

- ★ Infinitely Variable Finger-tip Speed Control
- ★ Standard Speed Range 20-1 or up to 150-1 for Special Applications
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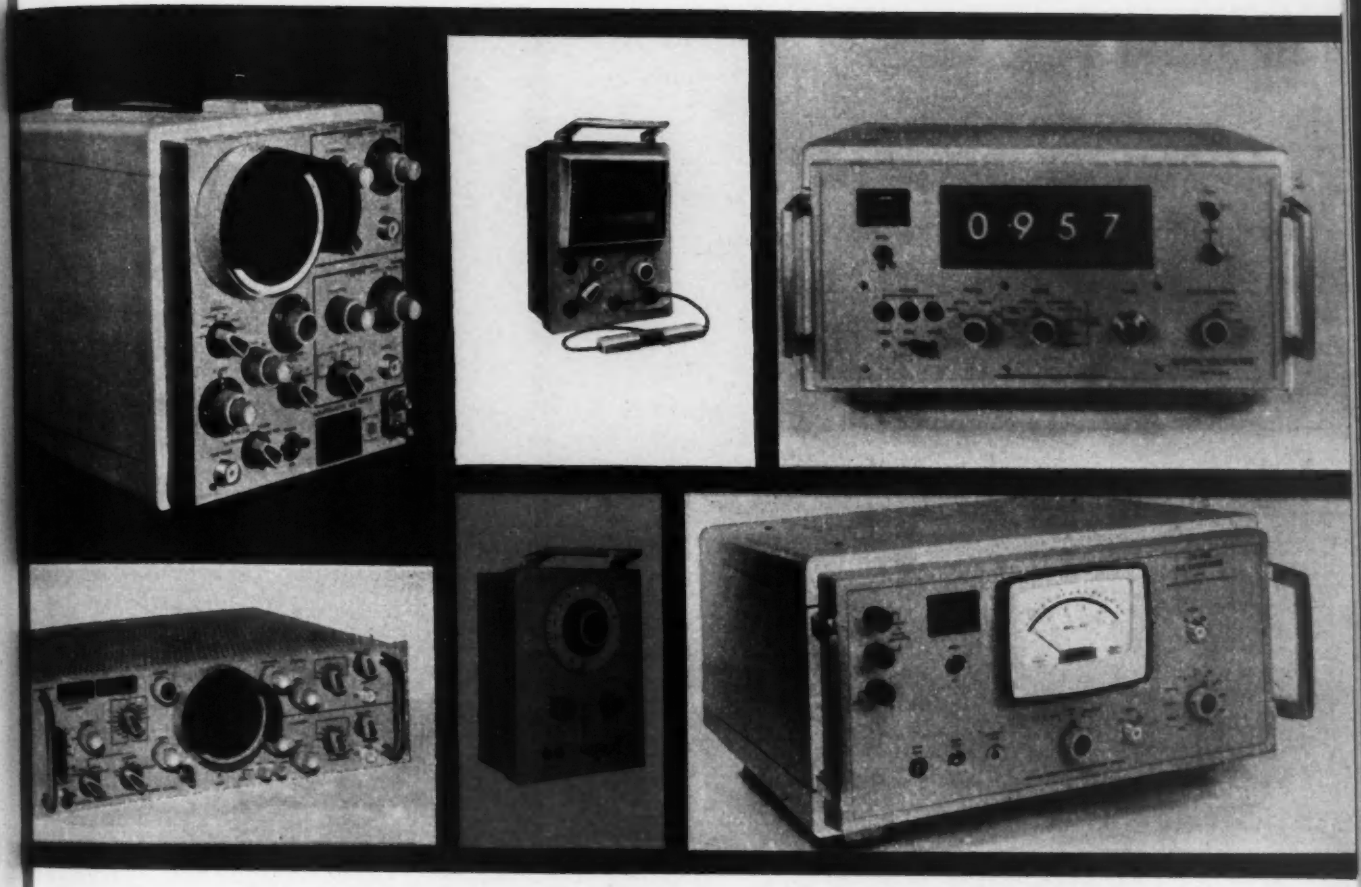
NR16

new Solartron instruments set new standards of design



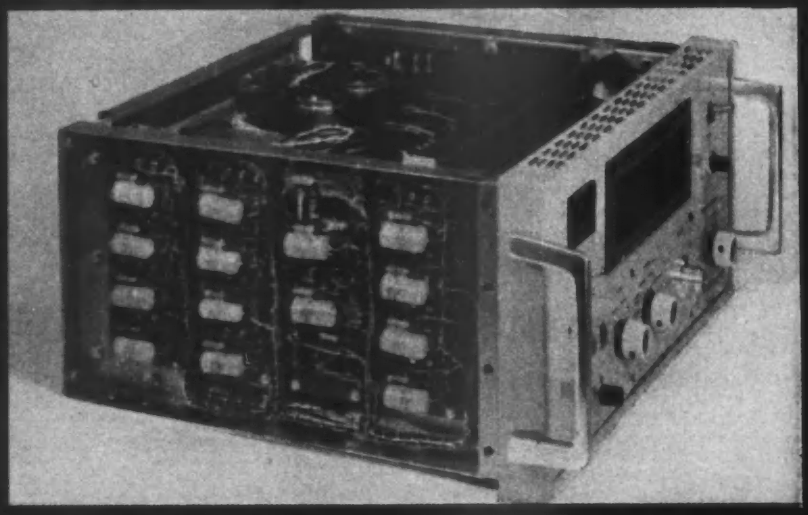
The instruments with the **Solartron new look** mark a big step forward in the science of instrumentation. Precision instruments designed for ease of operation—elegant methods of measurement and display, functional positioning of controls and in a style that has visual appeal.

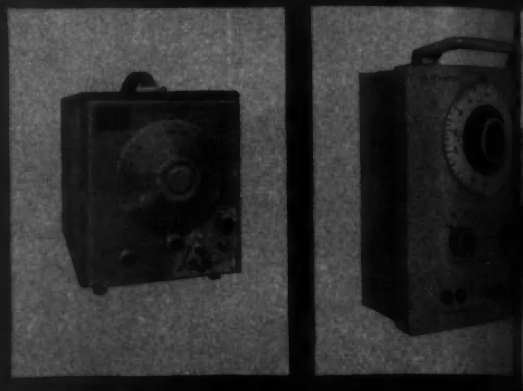
SOLARTRON

the forward look ——————————→

new ideas new circuit technique

Scientists and Engineers now reap the benefit from the forward thinking and planning in Solartron instrument design





NEW **Digital Voltmeters**

Decisive and consistent voltage readings by the method which obviates personal errors. A digital display in decimal form with polarity discrimination.

4 Figure DC Digital Voltmeter LM 902.2

100 μV — 1.599 KV in 5 ranges. Accuracy: 0.1% of max. reading on each range. Modes of operation: AUTO for continuous monitoring; SAMPLE for a 'spot' reading. Facilities for print-out and remote display unit.

AC Converter-Voltmeter LM 903

A self contained a.c. voltmeter, designed so that it may be used in conjunction with the LM 902.2 Digital Voltmeter to display rms voltage. 15 mV — 500 V rms (F.S.D. range). Frequency range 20 c/s — 5 Mc/s.

3 Figure DC Digital Voltmeter LM 901

(the first in the series of digital Voltmeters) has an overall range 0.001 V — 109.9 V, and is of compact modular construction suitable for incorporating in any existing equipment.

NEW **Oscillators**

Three new Solartron oscillators—two cover the frequency range 10 c/s — 50 Mc/s and the other, a fully transistorised R-C oscillator, covers 20 c/s — 200 Kc/s.

R-C Oscillator CO 1004

10 c/s — 1 Mc/s, accurate to $\pm$2.5%. 2 phases—0° and 180°. 0 — 20 V r.m.s. D_{TOT} <1% from 20 c/s — 200 Kc/s, <2% outside these limits.

Stabilised Amplitude Signal Generator DO05

350 Kc/s — 50 Mc/s, accurate to $\pm$2%. Additional 50 Kc/s spot frequency. 40 mV — 10 V (pk-pk). Amplitude stability: <2% change in 50 Kc/s—30 Mc/s, <5% in 30 Mc/s — 50 Mc/s.

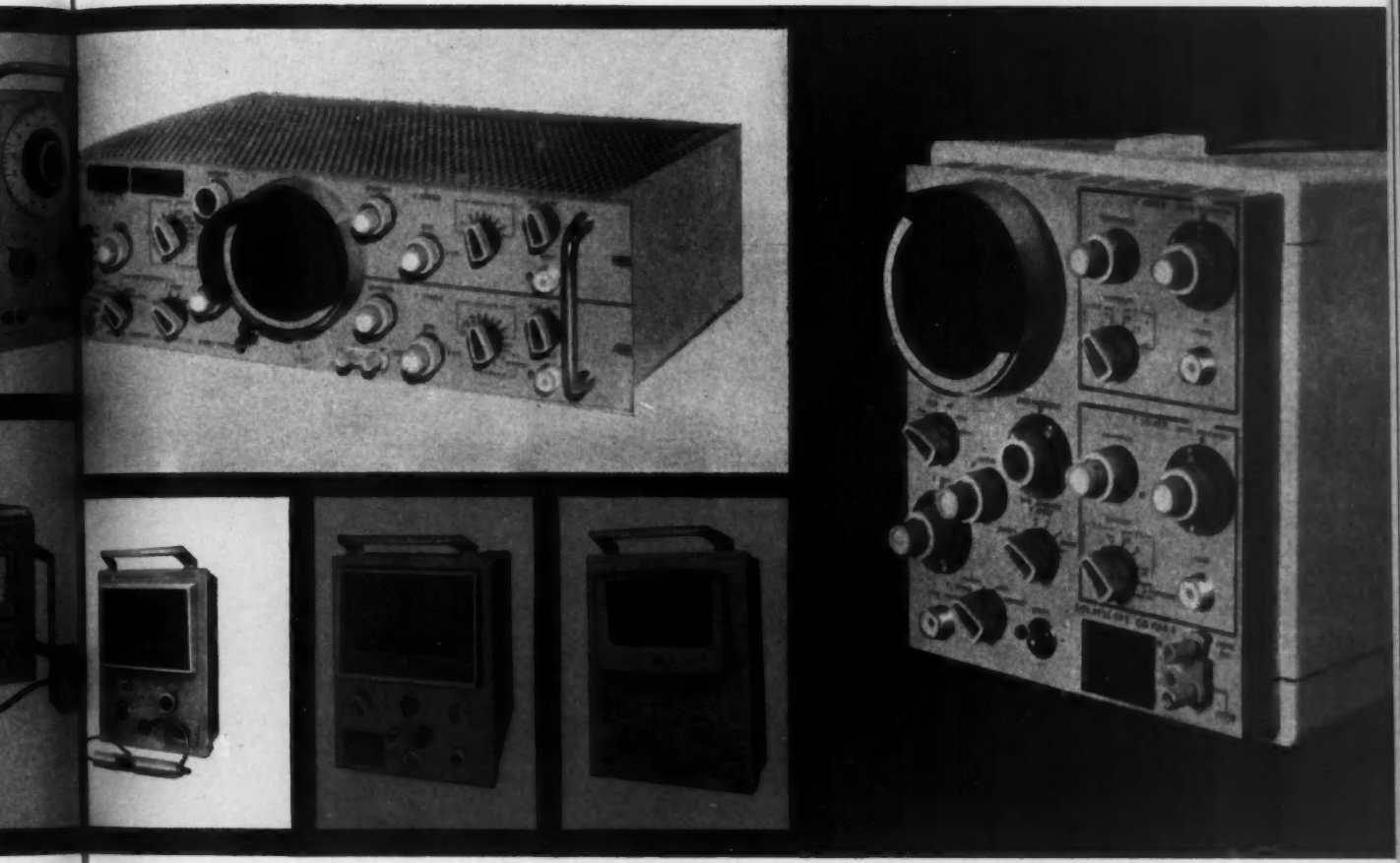
Portable R-C Oscillator CO 1008

—fully transistorised, operating from internal batteries.
20 c/s — 200 Kc/s, accurate to $\pm$5%. Frequency stability: 0.2% over 8 hour period. Amplitude stability: $\pm$2% over full frequency range.
0-1 V r.m.s. D_{TOT} <0.25% from 100 c/s—200 Kc/s, <1% outside these limits (for battery range 18–14V). Useful battery life 3 months.

SOLARTRON LABORATORY INSTRUMENTS LTD.

new presentation

SOLARTRON



NEW **Clip-Around Current Meter**

Current measurements by a method based on "Hall Effect"—enabling measurements to be made without loading or breaking the circuit.

Clip-Around DC Milliameter AM 1002

—fully transistorised and portable.

0-1 Amp in 5 ranges

0— 10 mA	±10% accuracy
0— 30 mA 0—100 mA 0—300 mA 0— 1 A	± 5% accuracy

NEW **Direct Reading f-C and L-C Meters**

—to give instant measurement of frequency, capacitance and inductance.

Direct Reading f-C Meter MM 1000

Frequency range:	0—100 c/s to 0—100 Kc/s (F.S.D.) in 7 ranges.
Accuracy:	±3%. (±5% on the two highest frequency ranges).
Capacitance range:	0—1000 pF to 0—0.3 μF (F.S.D.) in 6 ranges.
Accuracy:	± 2.5%.

Direct Reading L-C Meter MM 906

Inductance range:	0—3 μH to 0—300 μH (F.S.D.) in 5 ranges.
Accuracy:	± 3% F.S.D.
Capacitance range:	0—3 pF to 0—300 pF. (F.S.D.) in 5 ranges.
Accuracy:	± 3% F.S.D.

NEW **Oscilloscopes**

New versatile double-beam oscilloscopes—a portable, accurate measuring instrument (CD 1014.2) weighing only 22 lbs. and a compact rack-mounting version (CD 1016).

Features common to both oscilloscopes

DC — 5 Mc/s Bandwidth Y_1 and Y_2 amplifiers.

Y system

Sensitivity: Y_1 and Y_2 100 mV/cm — 100 V/cm
Y_2 a.c. input 1 mV/cm — 100 mV/cm (at reduced bandwidth).

Measuring accuracy: ± 5%.

Calibration: Square-wave ½ V pk-pk ± 1% at mains frequency.

X system

Writing speeds: 5 cms/μSec — 1 cm/sec (continuously variable).

Measuring accuracy: ± 5% for speeds < 1 cm/μSec.

Synchronisation: AUTO, TV Frame, TV Line and Normal switch positions.

'Level' and 'Stability' controls.

Direct access to X amplifier (DC coupled).

T.B. waveform available via C/F.

Display

The c.r.t. is a twin-gunned 3AZP31; P7 and P11 phosphors are also available. Vertical deflection of each trace 5.5 cms. Facility for external Z modulation.

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In addition to the new items described here, if you would like to keep up-to-date on all *Solartron instruments, please*

complete and return this page – now!

to the MAILING LIST SUPERVISOR
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COX LANE, CHESSINGTON, SURREY

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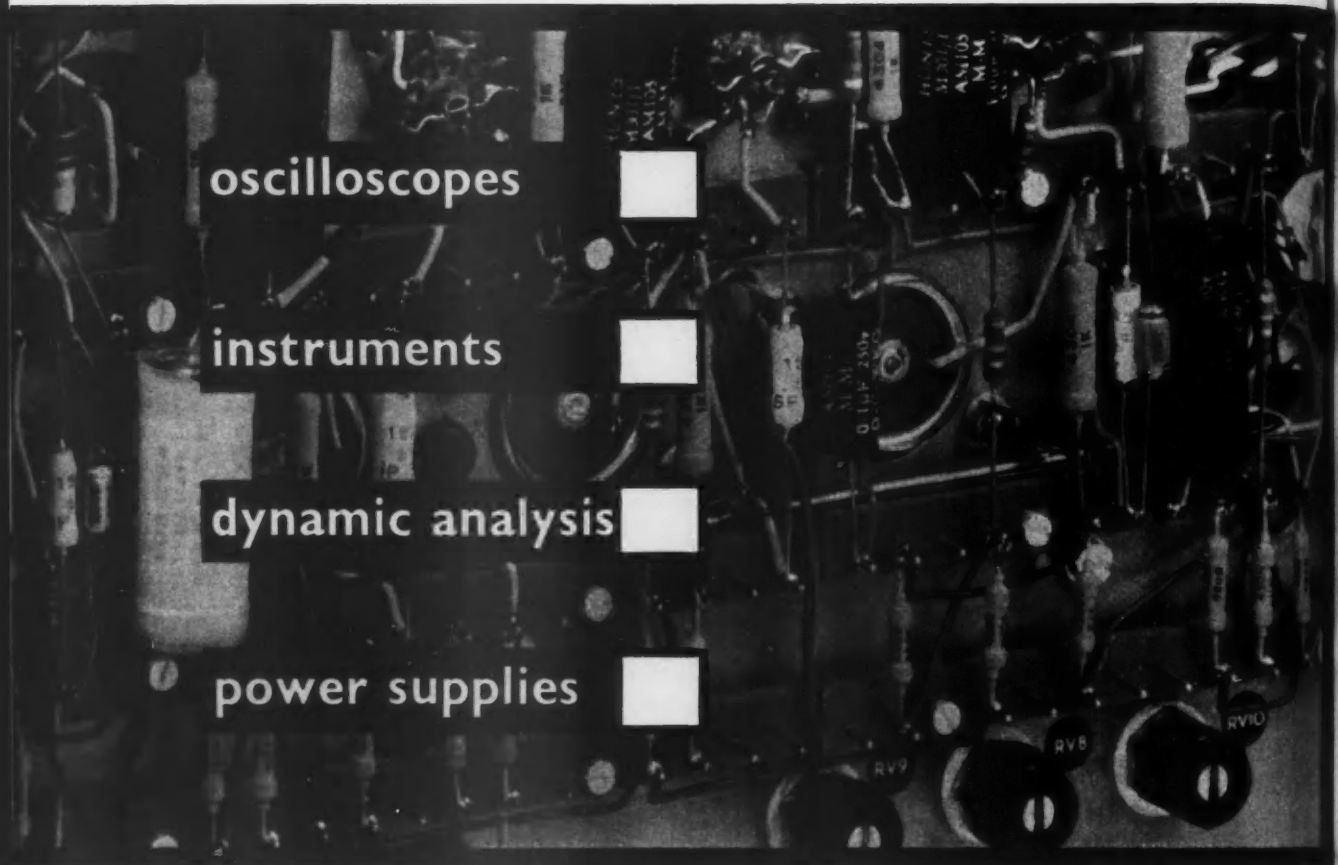
Beauty more than skin-deep — look inside these good-looking new instruments and see the advanced circuit design, meticulous workmanship, finest materials and components.



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A Member of the Firth Cleveland Group

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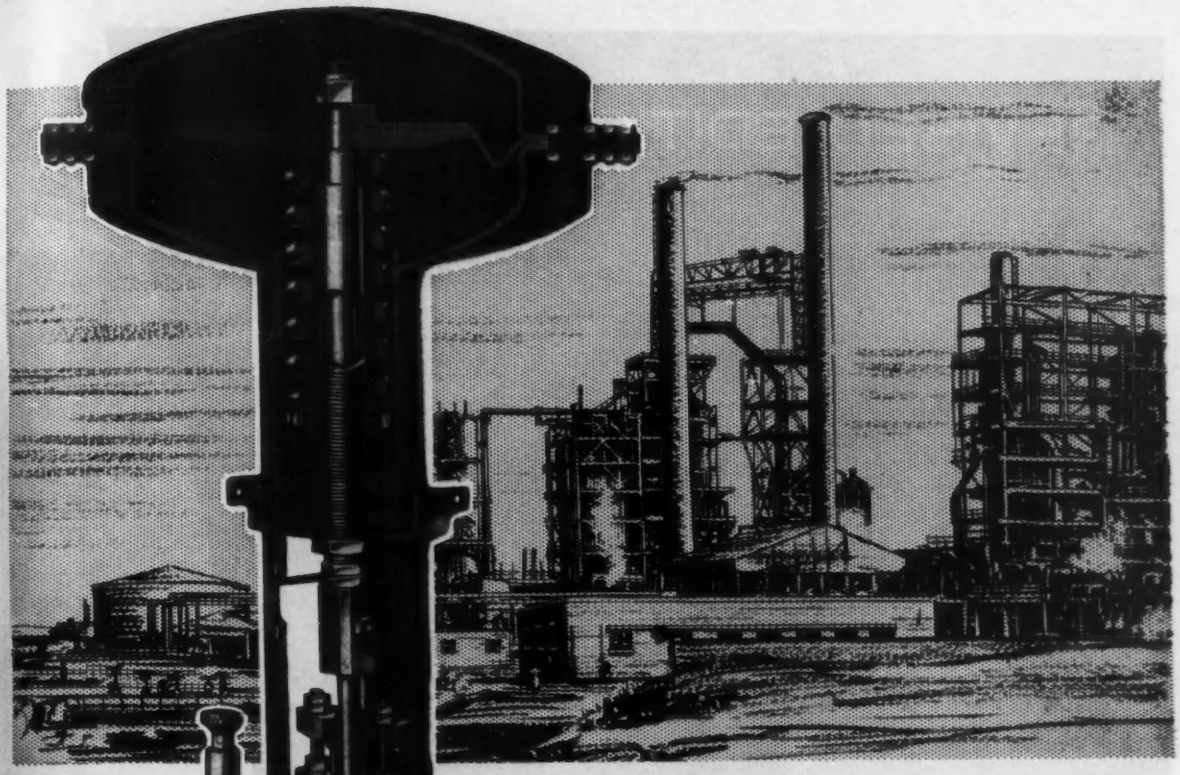

DIAPHRAGM CONTROL VALVES

Accurate, reliable, and economical, these Blakeborough types do full justice to the performance of the controlling instrument—hence their widespread use on modern automatic process control systems. An advanced and comprehensive range, well worth investigating.

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J. BLAKEBOROUGH & SONS LTD · BRIGHOUSE · ENGLAND

THIS IS THE GILBARCO GAUGE

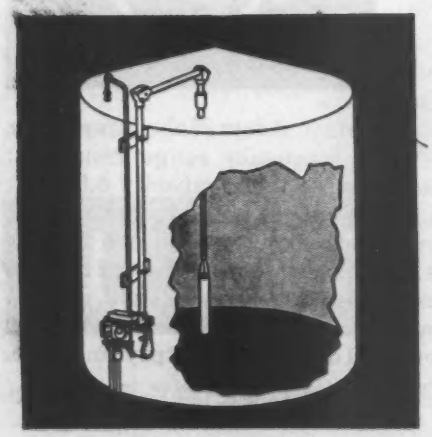
THE GILBARCO FIRTH CLEVELAND TANK GAUGE is a highly sensitive electronic device for local and remote indication of the level of liquids—or liquid interfaces—in deep tanks of all shapes and sizes. It gives continuous readings of level for liquids of any specific gravity and it is accurate within a few thousandths of an inch—this is particularly important in tanks with a large free surface area.

The instrument is suitable for use in hazardous areas and in extreme temperatures and it will operate data reduction or logging equipment. One remote indicator can be arranged to show the contents of up to 30 tanks in turn.

Routine maintenance can be carried out without taking the tank out of service.

These gauges are available to American Class 1 Group D Division 1 classification. We are shortly producing them to meet Buxton flameproof requirements.

The range of Firth Cleveland Instruments includes Electrical, Mechanical and Hydrostatic Tank Gauges, Pressure Operated Switches, and Pressure Relief Valves. We shall be happy to send you full particulars.



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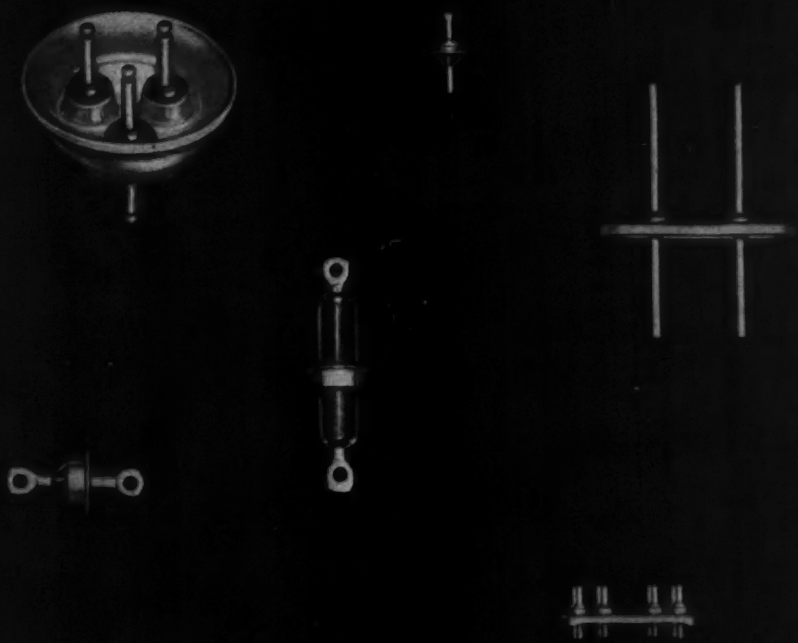

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SEALS HAVE PROVED THEIR
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From their wealth of experience and "know how" in so many fields, STC have evolved a range of seals to meet the most exacting standards of hermetic sealing. STC hermetic seals are available for many applications including:
Lead through insulators with flexible or solid terminations for transformers, relays etc.
Crystal base seals. Refrigerator seals.
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Write for publication No. MK/153 which gives details of these and other STC Hermetic Seals.

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THIS IS THE GILBARCO GAUGE

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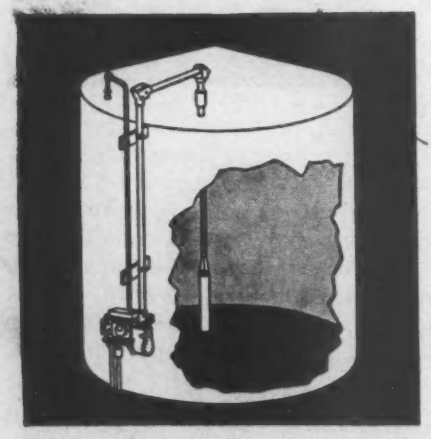

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STC hermetic seals

IN APPLICATIONS FROM TRANSISTORS TO REFRIGERATORS, **STC** HERMETIC SEALS HAVE PROVED THEIR PERFORMANCE AS HIGH GRADE COMPONENTS

From their wealth of experience and "know how" in so many fields, STC have evolved a range of seals to meet the most exacting standards of hermetic sealing. STC hermetic seals are available for many applications including:
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He could run a Jag on his print bill...

. . . not that he's likely to, of course; Suggy's the Bullnose Morris type if ever there was one. I must have told him about our Gestelith a hundred times before the message began to get through. Well, I like old Suggy so I ran him over to my place one day and we watched Stan run off a few pages of the Bulletin. That did it. Two hours later Suggy was in his shirt-sleeves learning the finer points from Stan . . . who's a founder member of the Gestelith fan club . . . and before the afternoon was up he'd run off a few impressions from a paper plate himself. Borrowed my telephone to arrange a demonstration at Gestelith . . . Astonishing, isn't it, the way some people'll shut their eyes to progress, then rise to a new idea when you least expect it?

The Gestelith pays for itself as a fast, efficient duplicator (using paper plates typed in your own office) while offering all the potentialities of the most versatile printing process of all . . . offset lithography. Gestelith is unique in having controls designed on work-study principles, relieving the operator of much purely repetitive work.

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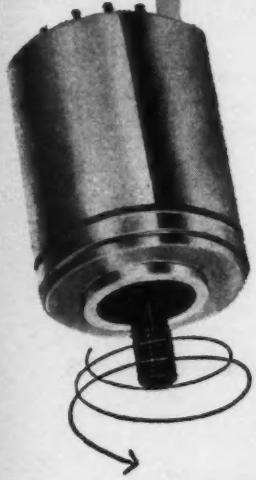
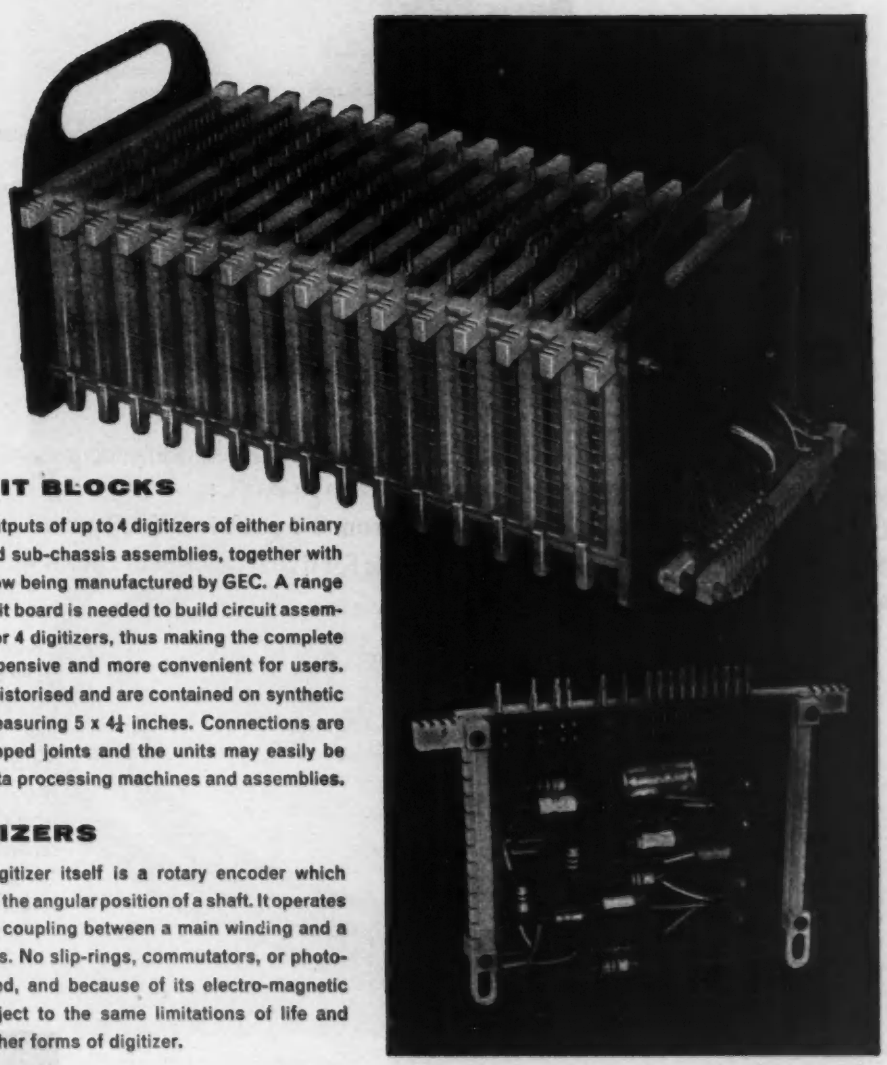
Standard Read Circuits for INDUCTION DIGITIZER SYSTEMS





STANDARD CIRCUIT BLOCKS

In order to present the outputs of up to 4 digitizers of either binary or decimal type, standard sub-chassis assemblies, together with decimal decoders are now being manufactured by GEC. A range of only five types of circuit board is needed to build circuit assemblies for reading 1, 2, 3 or 4 digitizers, thus making the complete equipment both less expensive and more convenient for users. The circuits are all transistorised and are contained on synthetic resin-bonded boards measuring 5 x 4½ inches. Connections are made by means of wrapped joints and the units may easily be integrated into larger data processing machines and assemblies.

INDUCTION DIGITIZERS

The GEC. induction digitizer itself is a rotary encoder which gives a representation of the angular position of a shaft. It operates by varying the inductive coupling between a main winding and a number of digit windings. No slip-rings, commutators, or photo-electric devices are used, and because of its electro-magnetic operation it is not subject to the same limitations of life and environment as most other forms of digitizer.

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Smee's GEC 70

static and

High output

Low temperature drift

All-round accuracy

Single-ended pressure transducer type 1029

Sensitivity	60 mv/v
Non-linearity and hysteresis	1%
Zero drift	better than 0.01% /° C
Thermal co-efficient of sensitivity	.02% /° C up to 200 p.s.i. .05% /° C above 200 p.s.i.

Differential pressure transducer type 1028

Sensitivity	30 mv/v
Non-linearity and hysteresis	1%
Zero drift	better than 0.01% /° C
Thermal co-efficient of sensitivity	.02% /° C up to 200 p.s.i. .05% /° C above 200 p.s.i.

Rugged N E P single-ended and differential pressure transducers accurately measure static and dynamic pressures at temperatures up to 200°C.

Gauge or differential fluid pressure ranges from 0-5 p.s.i. to 0-5000 p.s.i.

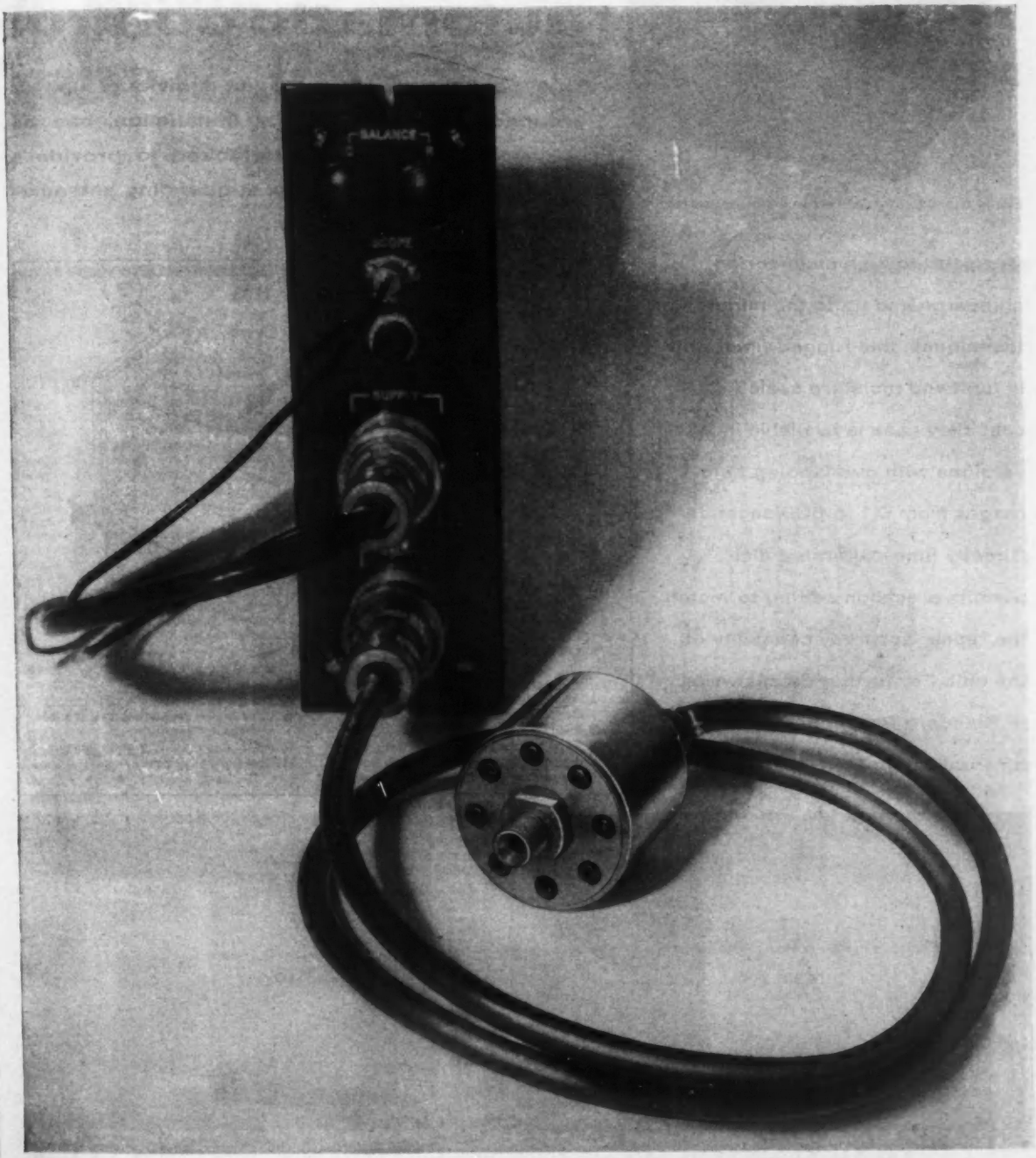
N E P inductive type transducers are suitable for dynamic pressure analysis with almost any fluids.

These transducers are designed to be used in conjunction with the N E P oscillator-demodulator unit. This provides an output proportional to the fluid pressure which can be used for operating controllers or can be recorded on the N E P process-free Direct Writing Galvanometer Recorder.

Suppliers of recording instruments and systems to the aircraft and G.W. industries, Government establishments, Admiralty, etc., A.I.D. approved

N E P

dynamic pressures at 200°C



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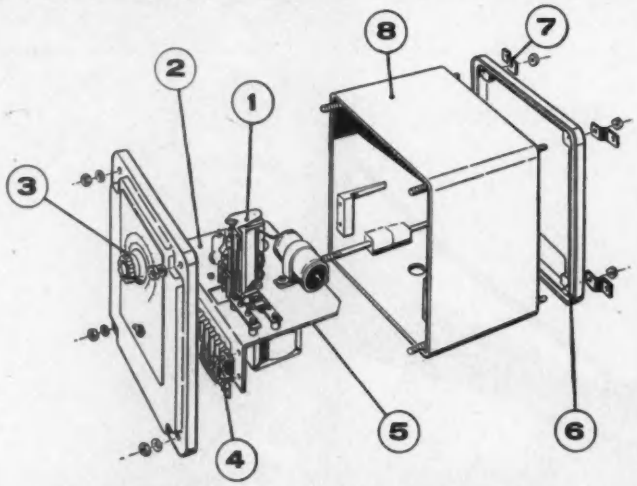
Exterior showing calibrated dial covering two typical ranges.

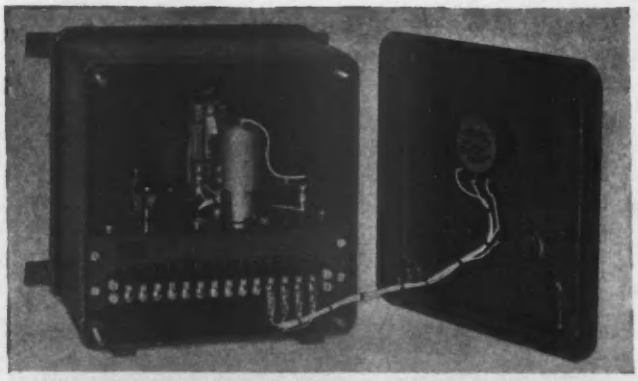
Now-flexible precision timing for *low cost* automatic control

This new timer, either as an individual unit or grouped in a multi-interval installation, can be electrically initiated or interlocked to provide a simple solution to complex sequencing and automatic control requirements.

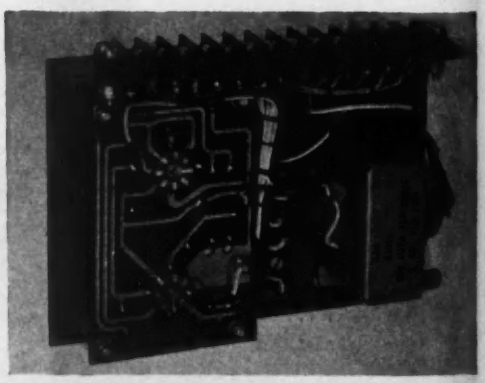
Designed to high engineering standards and up to the minute techniques, this rugged timer unit in dust and moisture sealed cast alloy case is available in six versions with overlapping time ranges from 0.1 to 500 seconds. Directly time-calibrated dial permits precision setting to match the repeat accuracy capability of the unit. For further details write to Standard Products Division for Publication D.6111-01.



1 Application proved relay with heavy duty contacts
2 Easily withdrawable chassis
3 Time calibrated dial for accurate setting
4 Accessible customers' connections
5 Printed circuit sub-chassis
6 Case sealed against ingress of dirt and dust
7 Adaptable mounting arrangements
8 Cast light alloy case



Sealed front cover removed showing simplicity and ease of access.



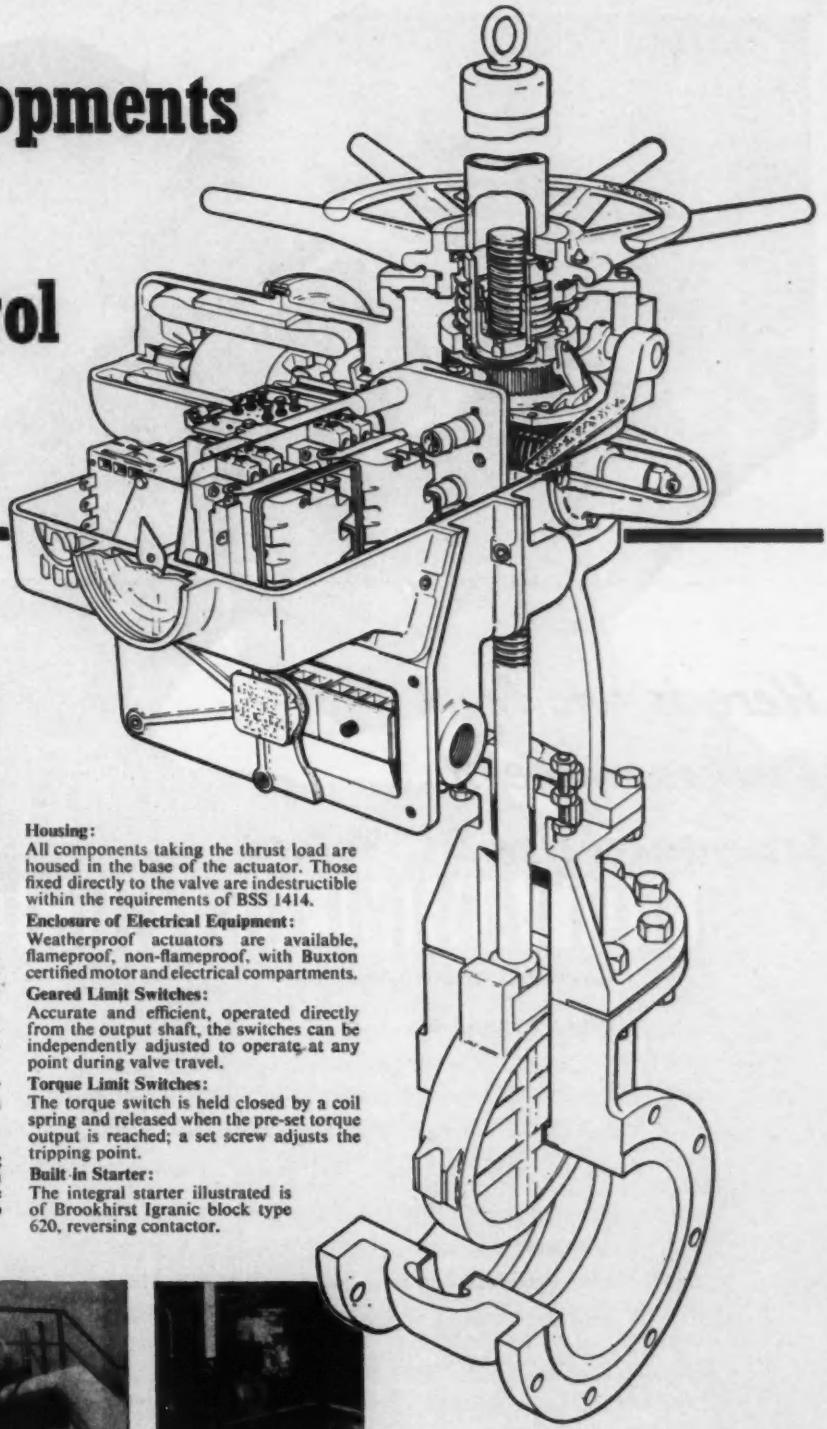
Printed circuit construction ensures high performance at low cost.

LANCASHIRE DYNAMO ELECTRONIC PRODUCTS LIMITED

S.P.6 RUGELEY · STAFFORDSHIRE · ENGLAND Metal Industries Group

Manufacturers of the world's widest range of industrial electronic control equipment

New developments in Rotork valve control



Valve manufacturers and users all over the world have helped Rotork develop their new series of electric actuators — the 'A' range. Such practical advice, coupled with Rotork's comprehensive experience of valve control, ensures that the 'A' range offers the most competent method available for automatically controlling any size or type of valve from any distance.

An entirely new manufacturing and selling organisation has been created to keep pace with the growing international demand for Rotork actuators. Highly competitive prices and good deliveries on a world-wide scale are assured by the overseas manufacturing and sales facilities now available in West Germany, France and Italy to augment U.K. production; as well as offices or agents in Holland, Switzerland, Australia, Canada and the Arabian Gulf.

A booklet covering every aspect of the Rotork 'A' range of actuators is available on request.

Outstanding features of the Top Handwheel 'A' Type Actuator illustrated are:—

Motor:
Squirrel cage, Stator/rotor unit, half hour rated and built to BSS 2613. Available with class 'A', 'B' or 'E' insulation.

Input Shaft:
Motor, worm and torque measuring spring pack are all on this common shaft, which slides in direct proportion to the torque transmitted to operate the torque switch to shut off the motor.

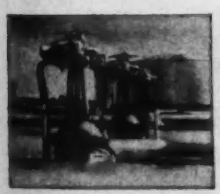
Housing:
All components taking the thrust load are housed in the base of the actuator. Those fixed directly to the valve are indestructible within the requirements of BSS 1414.

Enclosure of Electrical Equipment:
Weatherproof actuators are available, flameproof, non-flameproof, with Buxton certified motor and electrical compartments.

Geared Limit Switches:
Accurate and efficient, operated directly from the output shaft, the switches can be independently adjusted to operate at any point during valve travel.

Torque Limit Switches:
The torque switch is held closed by a coil spring and released when the pre-set torque output is reached; a set screw adjusts the tripping point.

Built-in Starter:
The integral starter illustrated is of Brookhirst Igranic block type 620, reversing contactor.

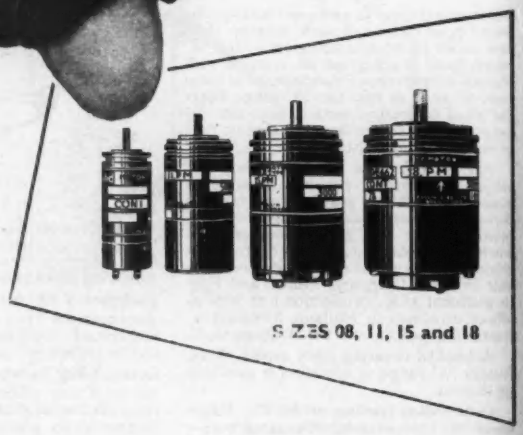


(Left and centre) Two typical overseas petroleum installations using Rotork actuators. (Right) Rotork actuators installed at the Vickers-Armstrong Hydraulic Test Plant.

Rotork have a controlling interest in all types of valves!

ROTORK ENGINEERING COMPANY LIMITED of BATH, ENGLAND. Tel: 64558

Here is one from the Pullin range of Standard size D.C. Motors



SIZES 08, 11, 15 and 18

Governed and ungoverned types available

Here is the International frame size 18, permanent magnet d.c. motor — one from the renowned Pullin range of precision, low voltage, permanent magnet d.c. motors designed for maximum performance and reliability even under most arduous operating conditions.

At 28 volts d.c. input: torque at 5000 r.p.m. 300 g.cms; stall torque, 900 g.cms. If speed governed: 3000 r.p.m. ±1%. As Tacho-Generator: 10v. per 1000 r.p.m.

Most types are available from stock.

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Synchros · Servo Motors
Motor Generators
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ELECTRICONTROLIMINATION

This is a method developed by progressive British Engineers in collaboration with Londex Ltd. The process is as logical as it is simple. An Engineer, faced with the problems of being in three places at the same time, keeping an eye on five things simultaneously and preserving some "spare" time to keen abreast of current developments, asks himself "Can I lumber anyone else with some of this lot?" One item comes readily to mind: electrical control. So our engineer—a shrewd methods-study man—uses a single time-saving, labour-saving movement to pick up the phone. He knows that for every different job of electrical control there is one piece of apparatus that is just right. He knows that LONDEX make 'em all. With Londex data book in hand, he crisply specifies "I want . . ." or, if there isn't time for that, he commands "Come and fix . . ." Because electricontrolimination is such a long word, it has been abbreviated for convenience to a simple telephone number: SYD 3111.

LONDEX

LONDEX LIMITED Electrical Automatic Control Apparatus
Anerley Works, London, S.E.20. Telephone: SYDenham 3111 (5 lines)

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is punched tape really the best input medium for numerical control?

Although 8-channel punched paper tape is only one of several numerical control input media, it is fast becoming the standard with builders of numerically-controlled machine tools. Why the swing to punched paper tape? There are three fundamental reasons:

(machine toolmakers say yes!)

1. **Paper tape coding is visible, tangible. You can see it, touch it, and with practice even read it.**
2. **Paper tape is continuous. Unlike cards, it can't get out of order.**
3. **Paper tape is easy to programme — preparation, verification, and reproduction of tapes are all handled on one inexpensive machine, the Friden Flexowriter.**

For the machine tool buyer, standardization on paper tape means great savings. It's so much easier (and less expensive) when *one* input system can control *all* of the numerically-controlled machines in a given plant.

If you're thinking numerical control, you'll do well to think *punched paper tape.*

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DTV

There's more to TMC ZETTLER RELAYS than meets the eye

But, nevertheless, close examination will reveal many of their superior qualities. And by using them you'll see, too, that they offer decided advantages in every aspect of industrial control involving electrical and electronic equipment. Where space is limited, their choice is destined to become a matter of course. *The wide range is capable of handling power from microwatts to kilowatts.*

BOTH ILLUSTRATIONS ARE OF THE TMC ZETTLER RELAY TYPE AZ210
(Actual size)

Exceptionally small · Robust · Screwless construction · 4 change-over actions · Fast speeds · Card operated springs · A general purpose Relay of outstanding merits · Available with printed circuit to suit British 0.1" Matrix.

THERE ARE TMC ZETTLER RELAYS WITH THESE FEATURES:

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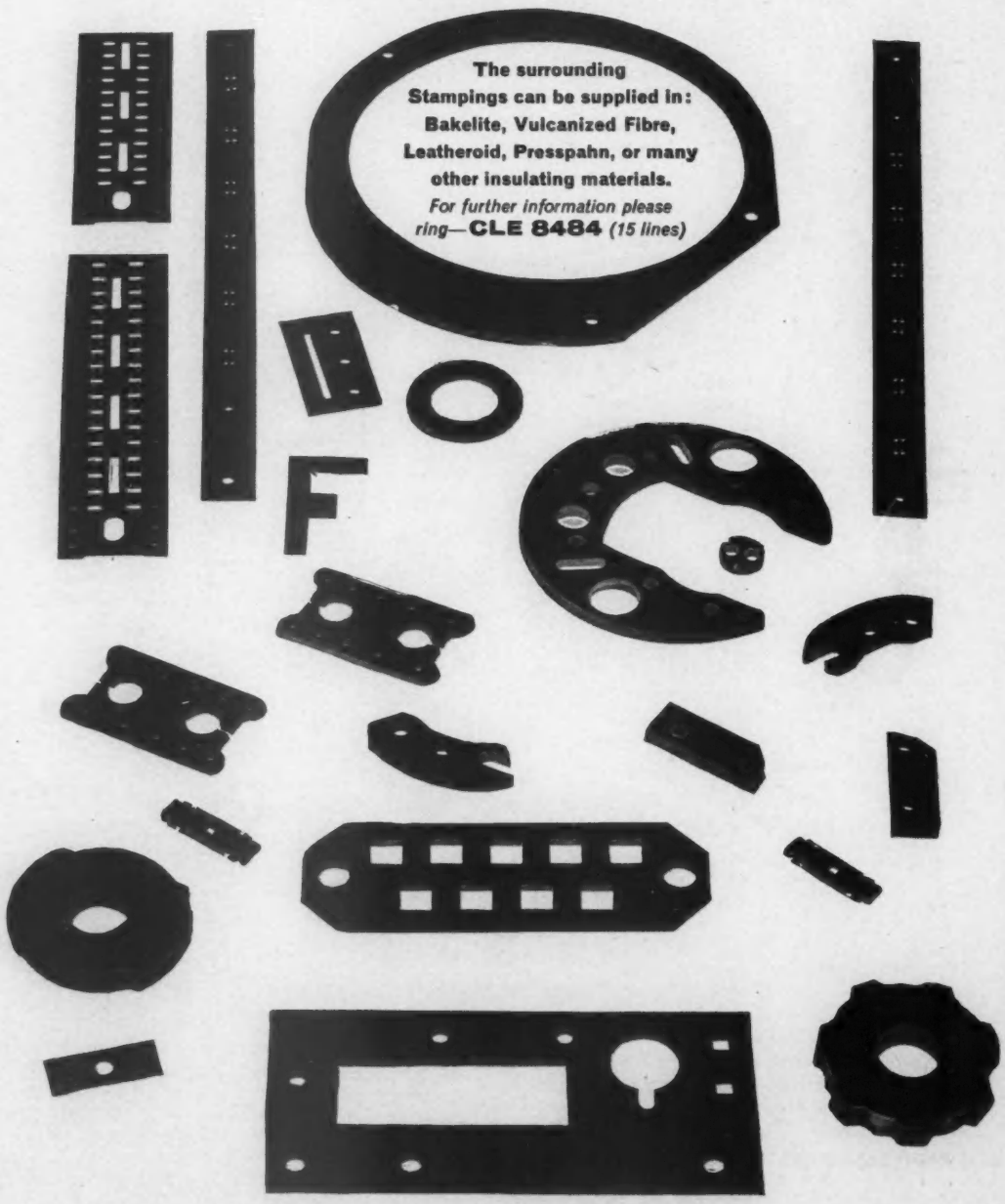

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A NEW SERVICE TO INDUSTRY AND RESEARCH

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A comprehensive Analogue Computer installation — staffed by experienced analysis, programming and operating personnel — has been established at the Solartron Research and Development Laboratories at Dorking, Surrey. The facilities provided by this installation are available on a time hire basis.

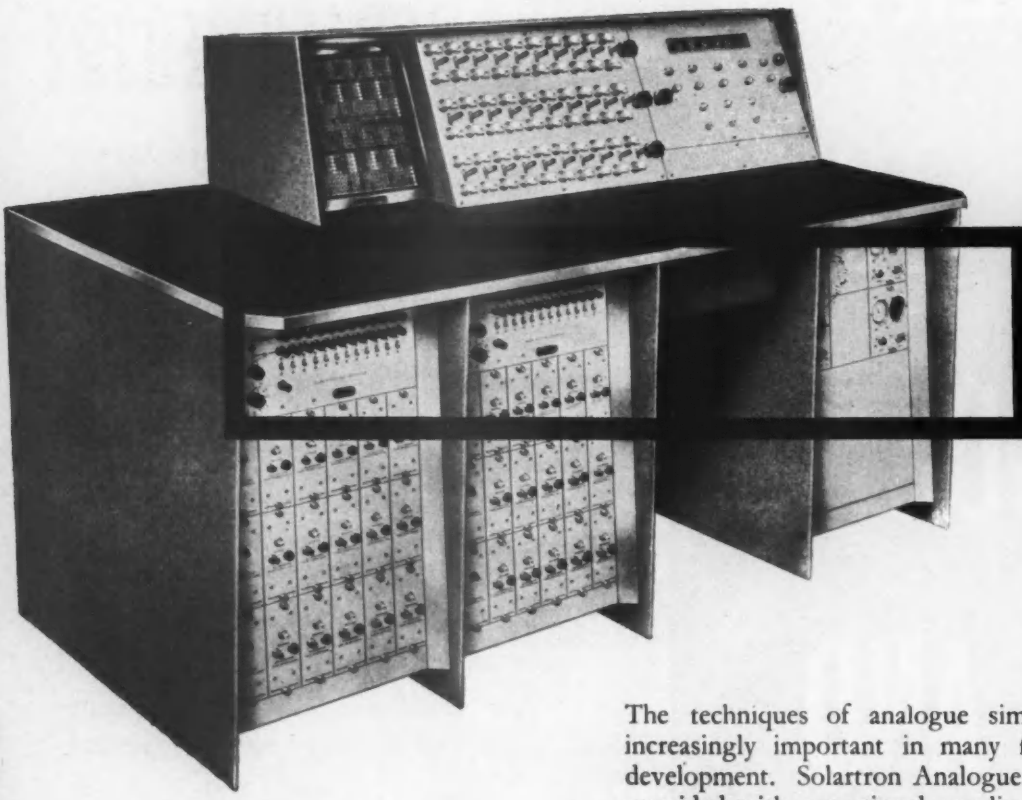
Full details of capacity at the new Solartron Analogue Computer Centre in Great Britain, including hire rates and operating arrangements, are available on request.

The installation incorporates computers of the type shown overleaf.

SOLARTRON

Space 30 Analogue Computer

foremost in flexibility



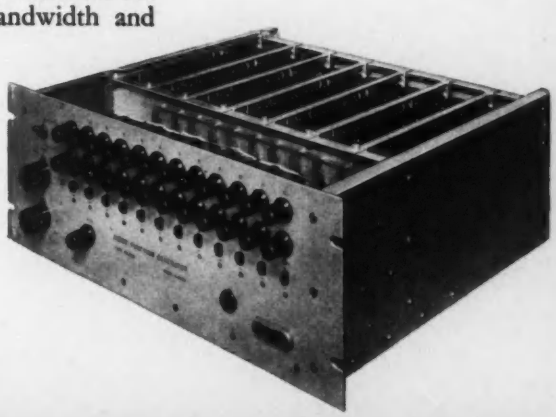
The techniques of analogue simulation are becoming increasingly important in many fields of research and development. Solartron Analogue Computers, which are provided with exceptional non-linear facilities, enable the average industrial user to directly simulate a wide range of physical systems without having to resort to special-purpose simulators.

The inclusion of programmed timing devices, servo multipliers and function generators, allows a great variety of non-linear and control problems to be directly simulated.

In order to assess the suitability of a particular computer for any given application, it is essential that expert advice be sought before the final specification is fixed. Accordingly, without obligation, Solartron will be pleased to provide application engineering assistance in the planning of computers to actual user requirements.

SOLARTRON

Designed for rapid, accurate setting-up of complex functions, the Solartron Diode Function Generator TR 829 is a 12-segment unit which sets a new high standard for resolving power, bandwidth and ease of operation.



Bandwidth;
DC to 100 c/s, with less than 1° of phase shift

Stability;
Long term, 0·25% or better

Segmental Drift;
Less than 100 mV

Segmental Gain Error;
Less than 0·2%

The Solartron Servo Multiplier and the Solartron Diode Function Generator open up new avenues of investigation to all users of Analogue computing equipment

Write now for literature

The Solartron Servo Multiplier TJ 725 is an extremely accurate general purpose potentiometric multiplier which is transistorised and employs gearless servo drive for exceptional dynamic performance.

Up to five variables may be simultaneously multiplied by one other, or up to the sixth power of a variable may be generated by this versatile unit.

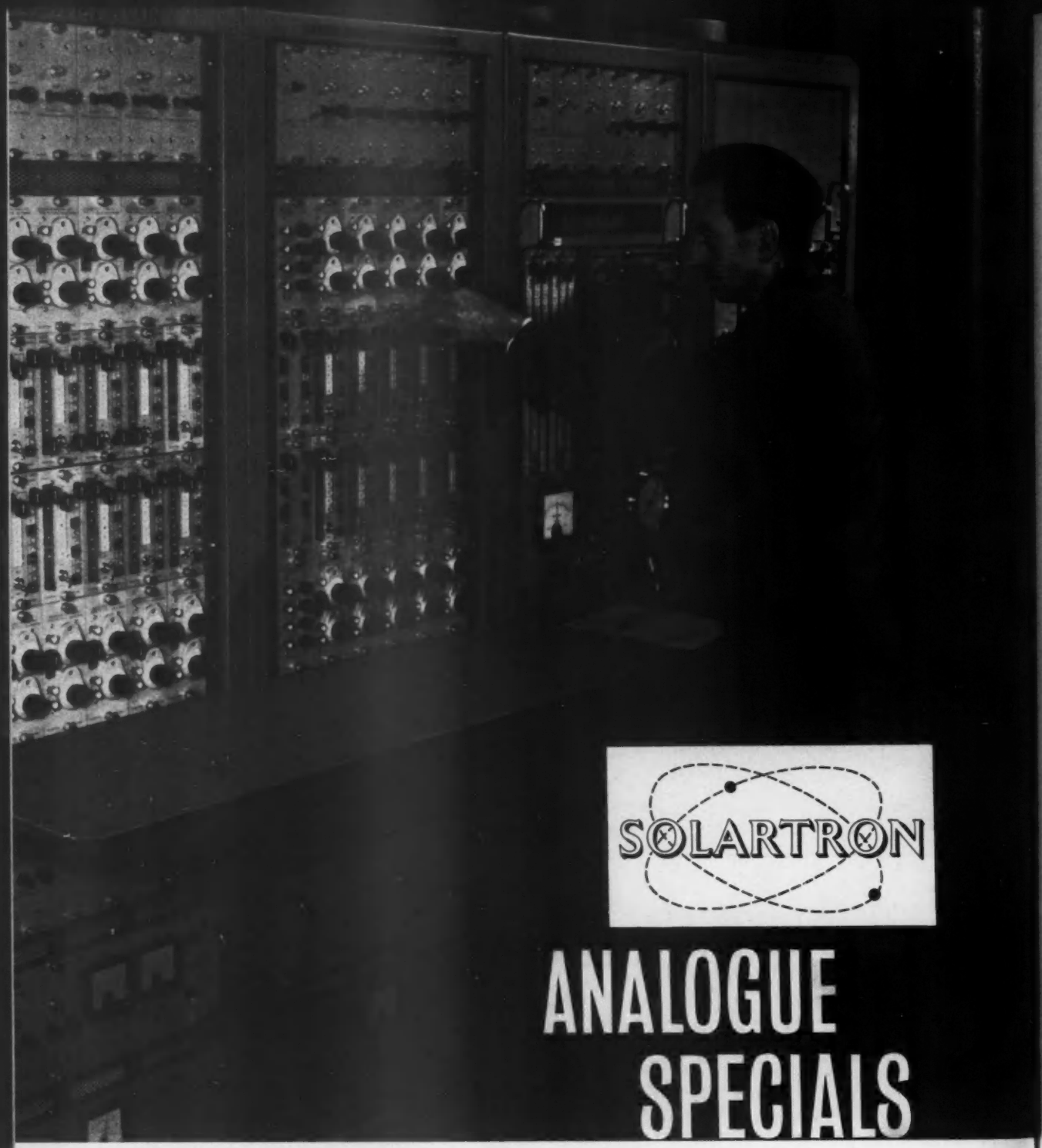
Servo Resolver TJ 961, incorporating sin-cos potentiometers, is also available.

Bandwidth;
DC to 10 c/s, at maximum amplitude with less than 1° of phase shift

Features;
Provision for preset function generation

Highly stable, transistorised power supply incorporated

Six-gang potentiometer assembly



SOLARTRON

ANALOGUE SPECIALS

A special analogue computer, tailored to your specific requirements, can be the answer to a tight budget or a simulation problem unsuitable for a general purpose computer.

When you order a Solartron Special, all the resources of the Solartron Electronic Group are available—the unrivalled experience acquired by skilled personnel at the Solartron Computer Centre in evaluating a wide variety of problems; also the immense technical knowledge gained in the establishment of a range of Standard Computers. A Special not only has the advantage of being designed to deal with your particular problem, but it also incorporates all the features which have made the Solartron SPACE Computer range invaluable to industry:

- High computing accuracy
- Precision digital voltmeter programming.
- Precision linear computing elements—or provision for patching all computing components externally
- High-accuracy non-linear capabilities
- Comprehensive control and repetitive operation facilities
- Precision system reference power supplies
- Simple extension of problem-handling capacity

A Solartron Special can be engineered from standard modules, quickly, and at a very competitive price. If you have a problem why not discuss it with Solartron Applications Engineers NOW? Write or phone:

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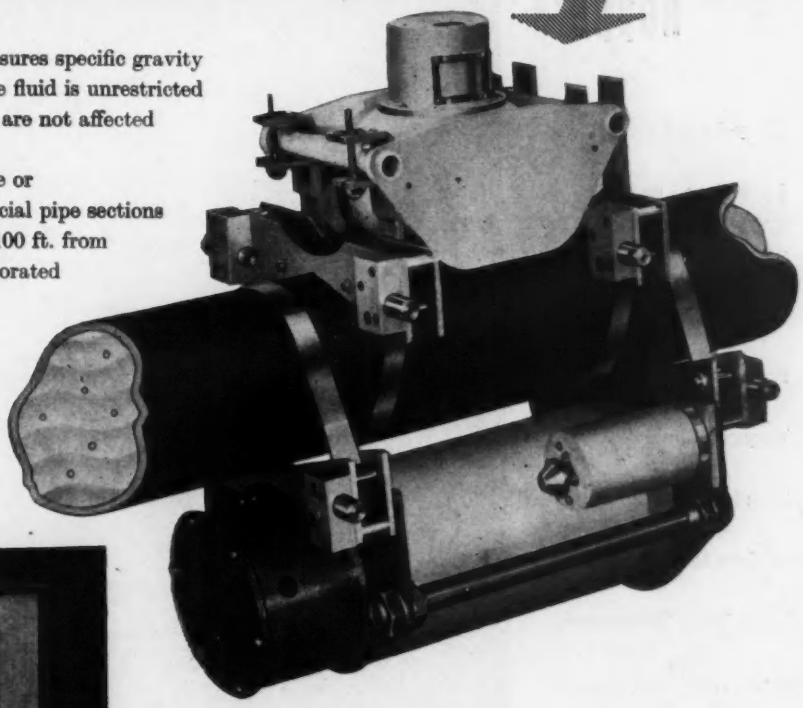

If you are concerned with—

Difficult chemical abrasive slurries, aggressive fluids, pastes, or inflammable liquids, then the Ekco N611 can probably solve an awkward measurement or control problem for you.

Consult the Ekco Electronics Technical Advisory Service without delay.

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SOUTHEND 49491

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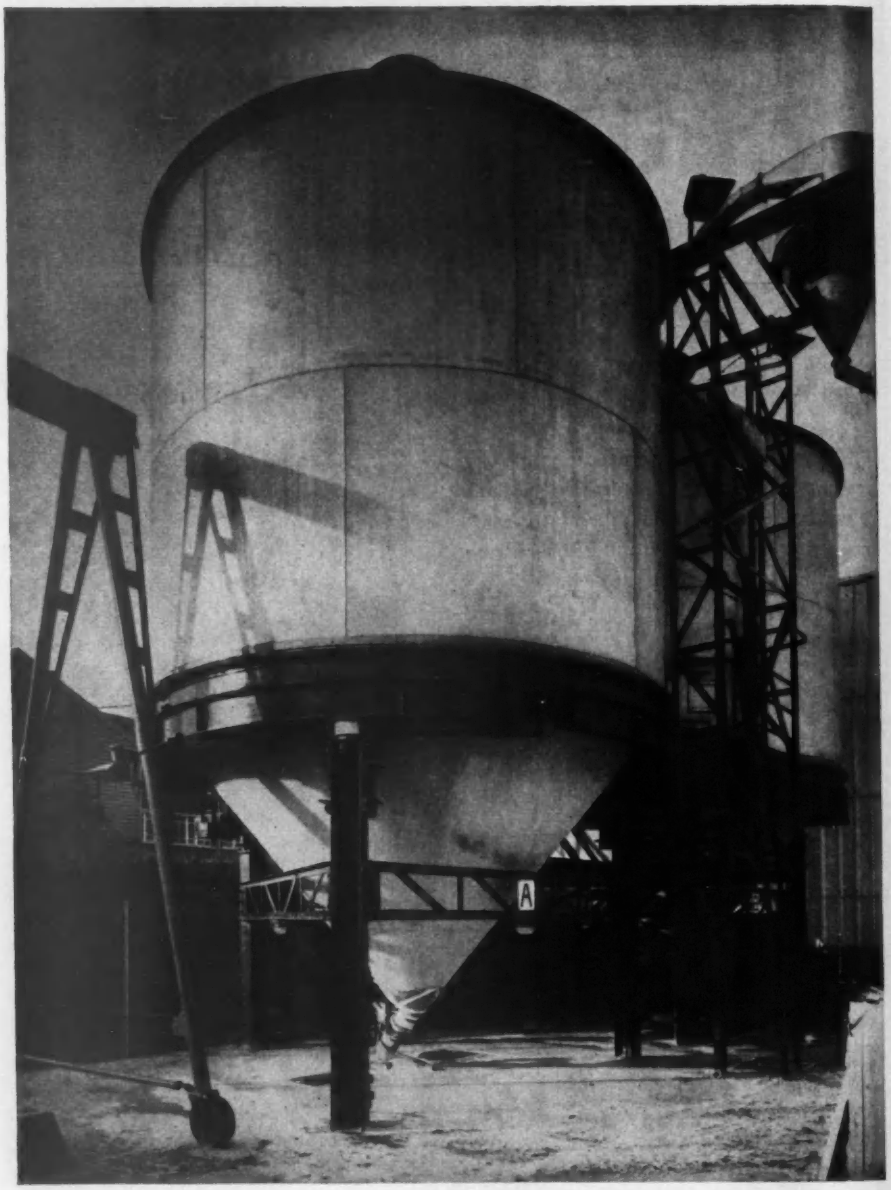
LOADCELLS for Process Control

weighing Polymer hoppers

Davy-United Heavy Duty Type Loadcells, each of 50 tons rating, weighing the contents of Polymer Hoppers at British Visqueen Limited. Each hopper is supported on three loadcells and indication of the contents weight is provided by a Honeywell Controls Circular Scale Instrument.



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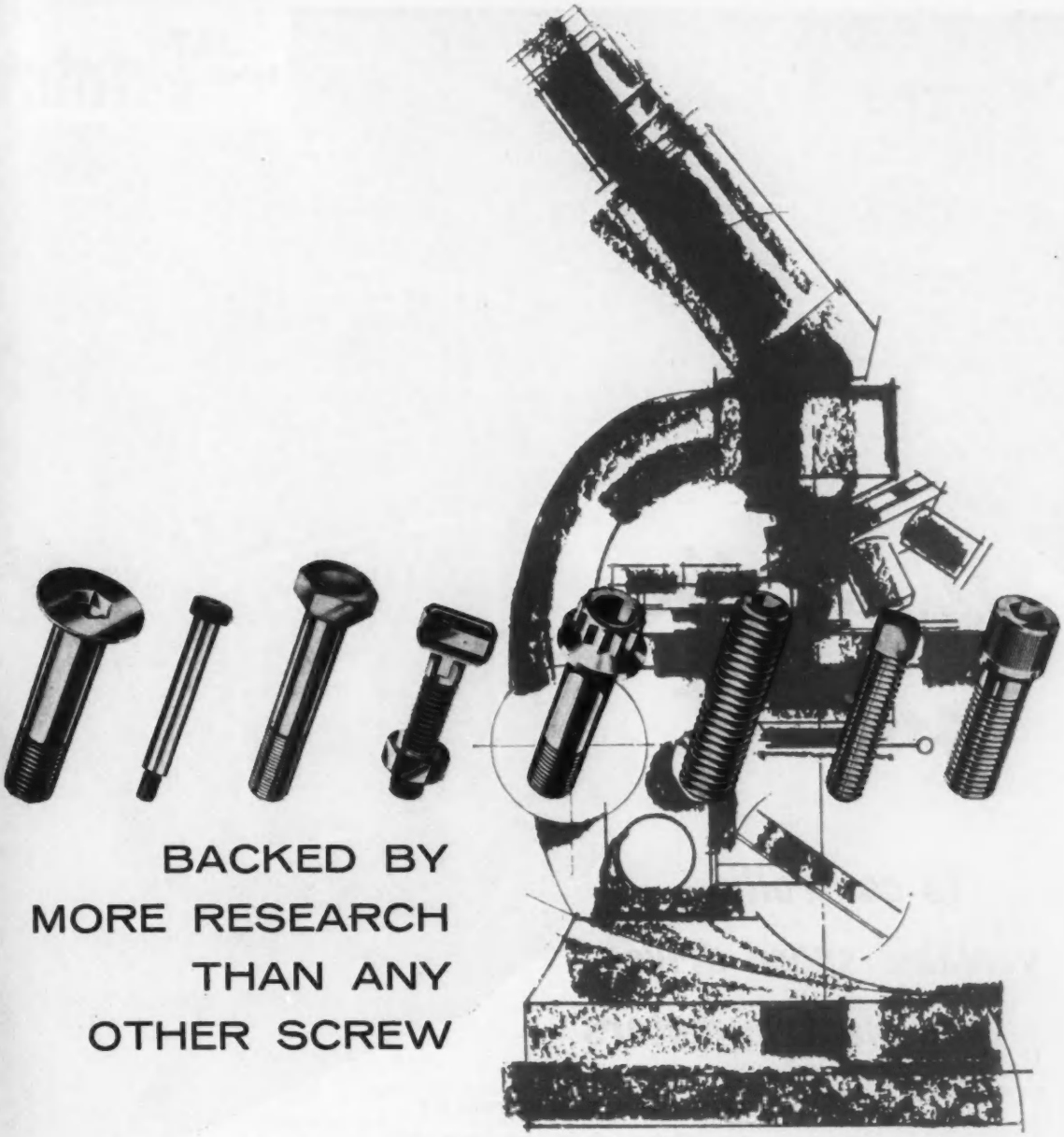

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Unbrako are making screws now to take strains which are still drawing board calculations. That is what Unbrako's genuine five-year lead means to industry. Designers can plan ahead in the confidence that the fasteners they will need already exist.

Unbrako screws are made by men with a wealth of experience, applying the skills of today to the needs of tomorrow, backed by intensive research and the most advanced production techniques.

Fastenings are no problem nowadays. Unbrako individual product leaflets, gladly sent free on request, will meet most of your needs. For special projects, the Unbrako man will be happy to call.

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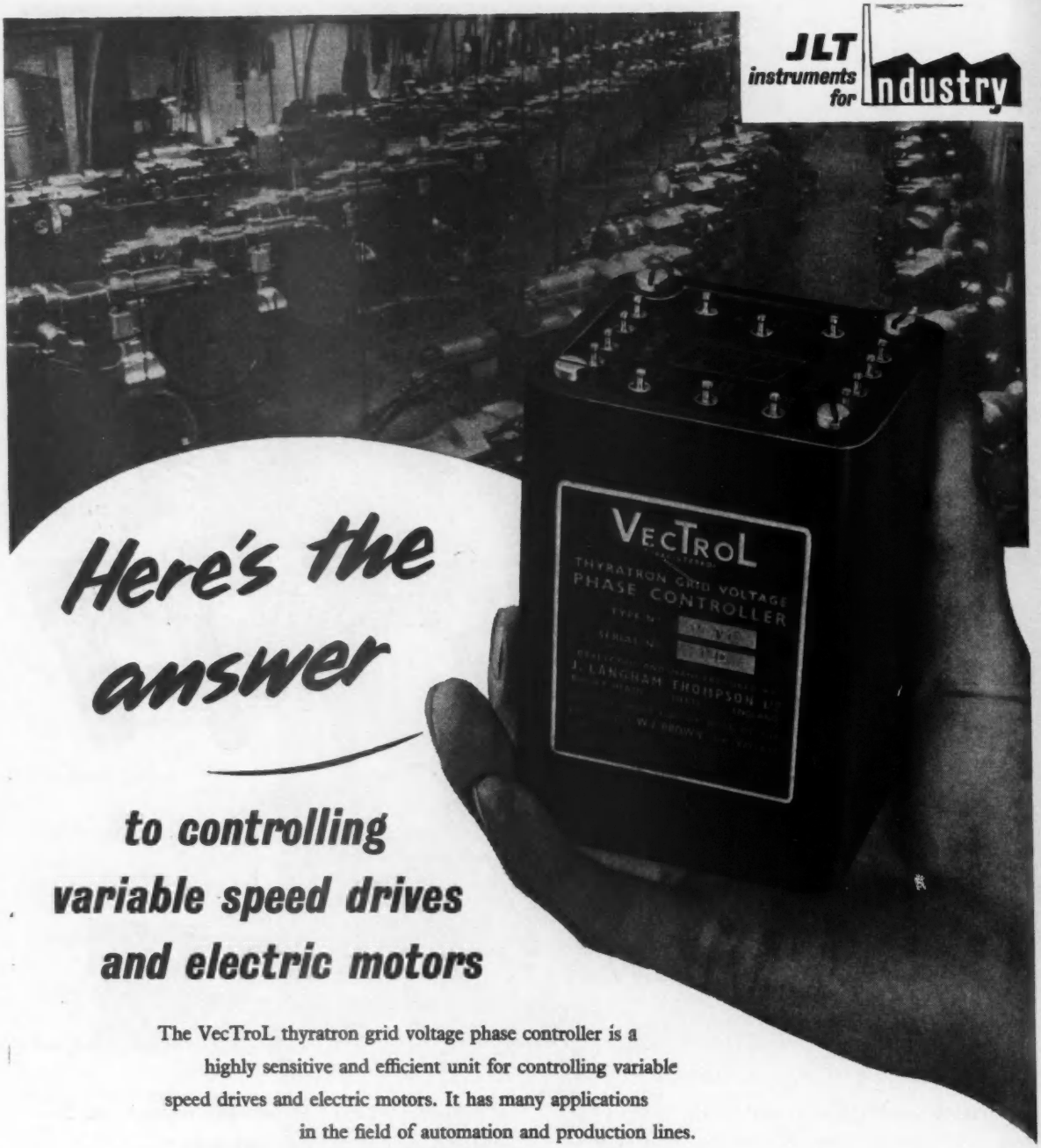
JLT instruments for Industry



Here's the answer

to controlling variable speed drives and electric motors

The VecTroL thyratron grid voltage phase controller is a highly sensitive and efficient unit for controlling variable speed drives and electric motors. It has many applications in the field of automation and production lines.

The unit is compact and robust being enclosed in a resin casting. There are no valves or unstable components and it has virtually indefinite life and servicing is completely eliminated.

Two models are available, LT-V1 for low signal source resistances, such as motors, and LT-V2 when source resistance is high, for example for photo cell circuits.

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VCT/1

from -55°C to +155°C

Plessey mark 5 connectors

This new range of aluminium Mark 5 connectors embodies the main features of the well-established Plessey Mark 4 connector plus additional characteristics for safe operation between −55°C and +155°C!

Designed specifically to provide thoroughly efficient and reliable service at the extended temperatures of modern requirements, the Mark 5 range has passed successfully Type Approval tests to the conditions specified in DEF 5321 (July 1958), maintaining a pressure sealing of 20 lb. p.s.i. between −40°C and +155°C. Where pressure sealing is not essential, efficient operation to −55°C is attained.

This standard of performance has resulted in the Mark 5 Connector being adopted by the Ministry of Aviation as the Pattern 104 connector.

Wiring and Connectors Division

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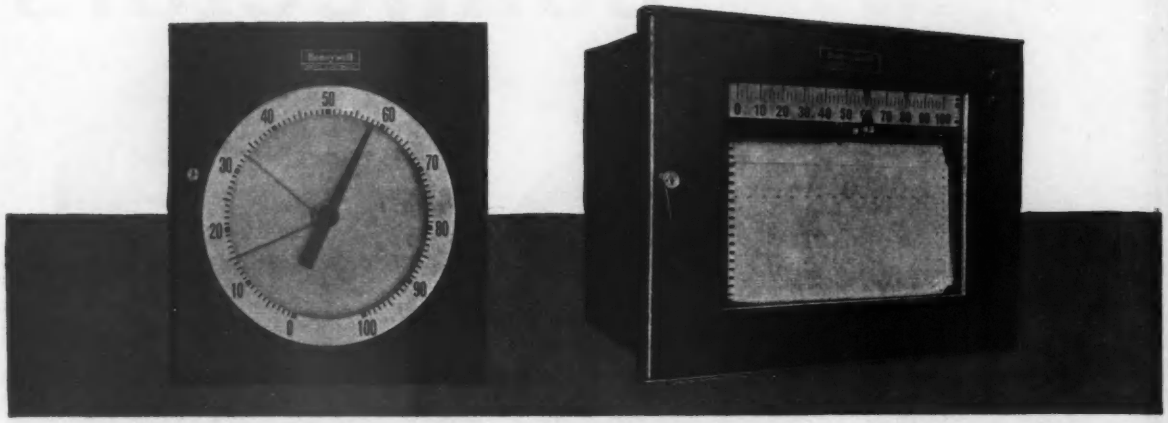
CW19a

New modular design...

makes *ElectroniK* potentiometers

easier to use and maintain



Now, four great new features add new operating and servicing ease to all ElectroniK circular and strip chart potentiometers.

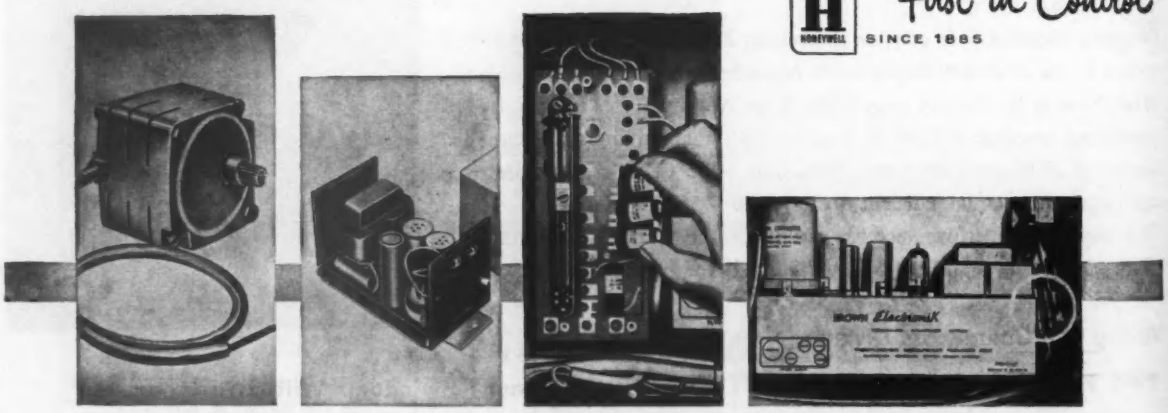
1 **New balancing and chart drive motors are sectionalized so that any major part can be replaced in two minutes.**
2 **A new constant voltage unit replaces batteries, standard cells and standardizing mechanisms.**
3 **A new measuring circuit, with quick-change range spools, simplifies range changing and reduces stray pickup.**
4 **A quick-connect feature permits removal of amplifier for service and its quick replacement.**

Now, modular design is combined with the traditional precision of ElectroniK potentiometers, to give you a greater value than ever in accurate, dependable measurement and control.
For full details write to Honeywell Controls Ltd, Ruislip Road East, Greenford, Middlesex. WAXlow 2333.

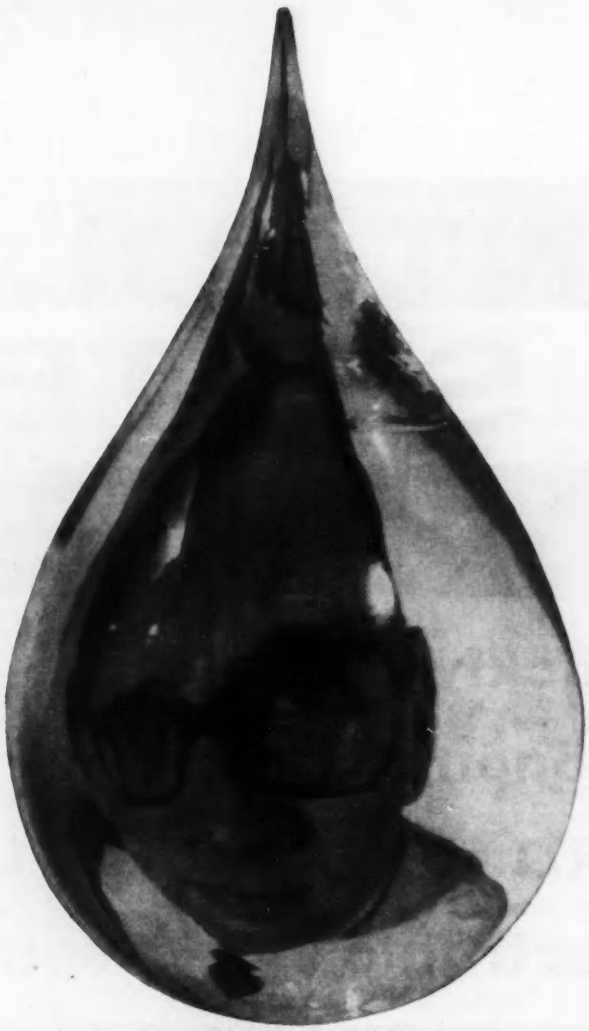
Honeywell

First in Control

SINCE 1885



1 Balancing Motor 2 Constant Voltage Module 3 Measuring Circuit Module 4 Amplifier Module



LOOKING FOR FLUIDS—with exceptional thermal stability—fluids that are water-repellent and retain good dielectric characteristics over a wide range of temperatures — that resist oxidation—have low volatility and show little change in viscosity with temperature —are ideally suitable for use in damping mechanisms—as heat transfer media—and for use in hydraulic, springing and coupling devices—GET THEM FROM MIDLAND SILICONES.

Remember—Midland Silicones Ltd have consistently set the pace for British progress in this fast developing field. Remember, too, that—while silicones cost more initially—this extra outlay is more than offset in terms of greater efficiency and long term economy.

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MSF 1

CONTROL SYSTEMS TAKE SHAPE

quickly—accurately—economically with MULLARD EQUIPMENT LIMITED electronic sub-assemblies

The range of electronic sub-assemblies available at Mullard Equipment Limited enables them to offer a unique service in the design and manufacture of industrial control systems to meet individual customer's special requirements. At the same time, customers wishing to design and manufacture their own systems are able to make use of these versatile sub-assemblies and will receive the fullest co-operation in the solution of design problems.

Electronic sub-assemblies make possible the speedy, accurate and economical production of control systems because they provide the designer with nearly all the basic circuits required. These circuits are of proven design and reliability and, because they are quantity produced, economical in price.

Once a control system has reached block diagram, it is possible to translate each function into one or more sub-assemblies. Prototypes and complete systems can then be quickly produced. The manufacturing process, and indeed the flexibility of the system, is simplified since many of the sub-assemblies are 'plug-in' types, whilst others require only solderless 'crimping' for interconnection.

NORBIT BUILDING BRICKS

These transistor circuits provide all the switching and timing facilities normally required. Using a d.c. technique, the basic switching units, together with such associated 'building bricks' as timers and counters, are capable of switching a maximum power of some 150w direct.

Applications of Norbit building bricks include sequential programming, machine control, automatic lift control, safety circuits and transfer line control.

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In many systems, there is the requirement to measure a phenomenon and produce a control output when a particular value is reached. These plug-in decade units provide an ideal means of achieving this type of control. As well as straight-forward counting of passing objects or physical movements, suitable transducers enable such factors as time, size, length and weight to be 'counted' by the sub-assembly. Each decade is capable of giving ten control outputs, hence complete control of a great variety of processes is possible.

SUB-ASSEMBLIES · ASSEMBLIES · SYSTEMS
– a complete service to industry

Only two of the range of electronic sub-assemblies for industrial control are discussed in this advertisement; full information on the complete range, which includes power supply units, and on the design and advisory service are freely available.

A regular 'Sub-Assemblies Bulletin' is now being published; its contents will be of considerable interest to both engineers and management. To ensure that your name is on the mailing list, you should write to Mullard House.

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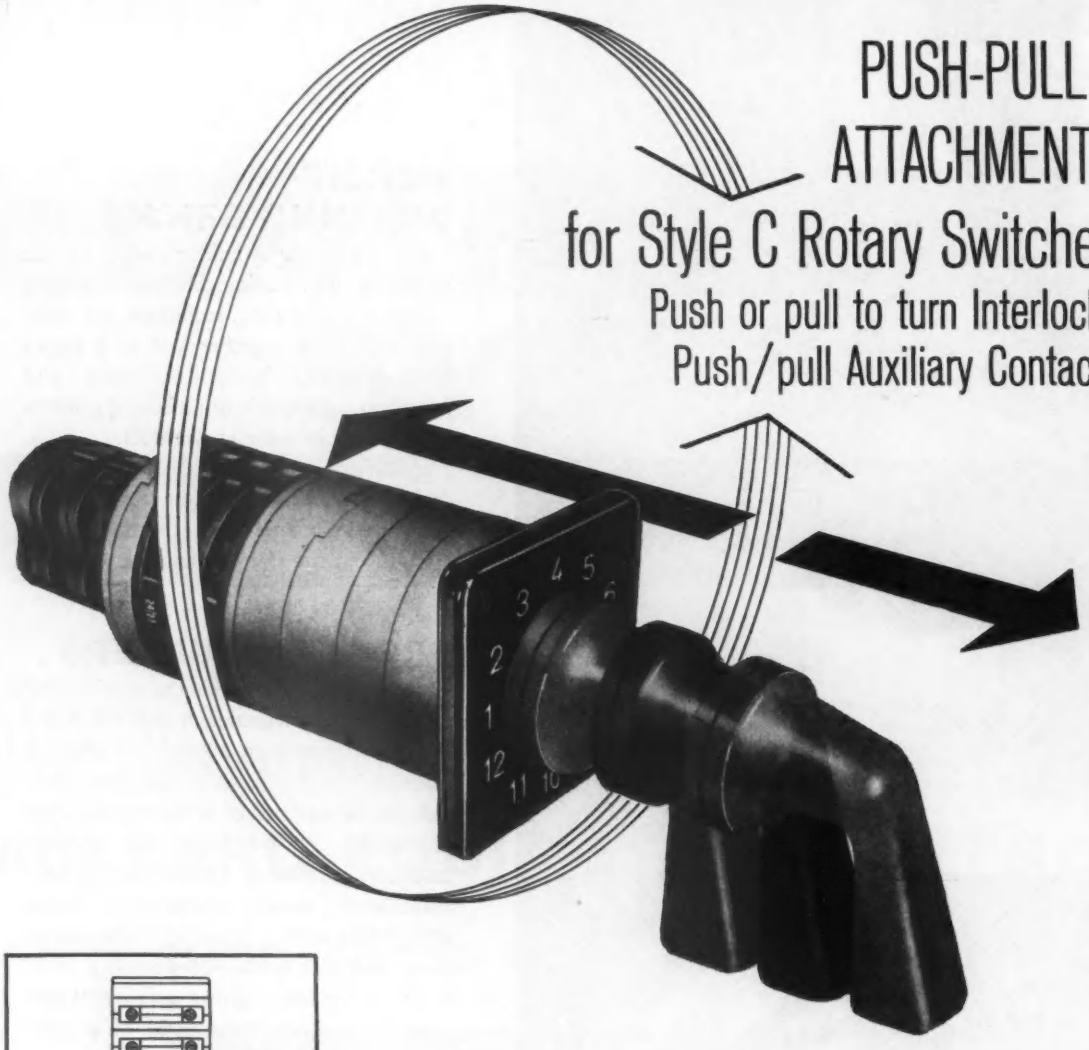
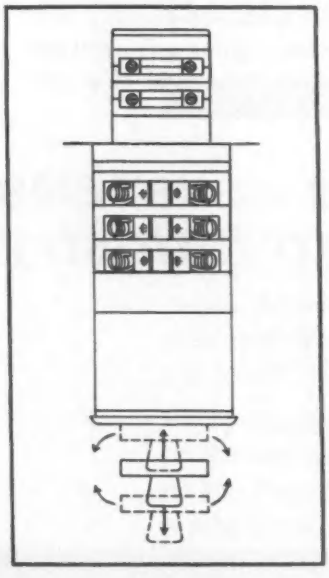
Push or pull to turn Interlocks
Push/pull Auxiliary Contacts





In addition to the normal switching sequences by rotary movement, the operating handle may be pushed or pulled from its rest position against a spring return, by which N/O or N/C contacts are closed or opened. Thus the unit is not only a selector switch, but also a push-pull device. The interlock section can be arranged to prevent the handle from being pushed or pulled in any selected position, or to prevent rotation in any particular level.

Typical applications include: Off load selection, contactor interlocking, contactor closing and multi-motor control. The system can save much panel space, simplify control and allow closer protection of equipment. May we send you further particulars?

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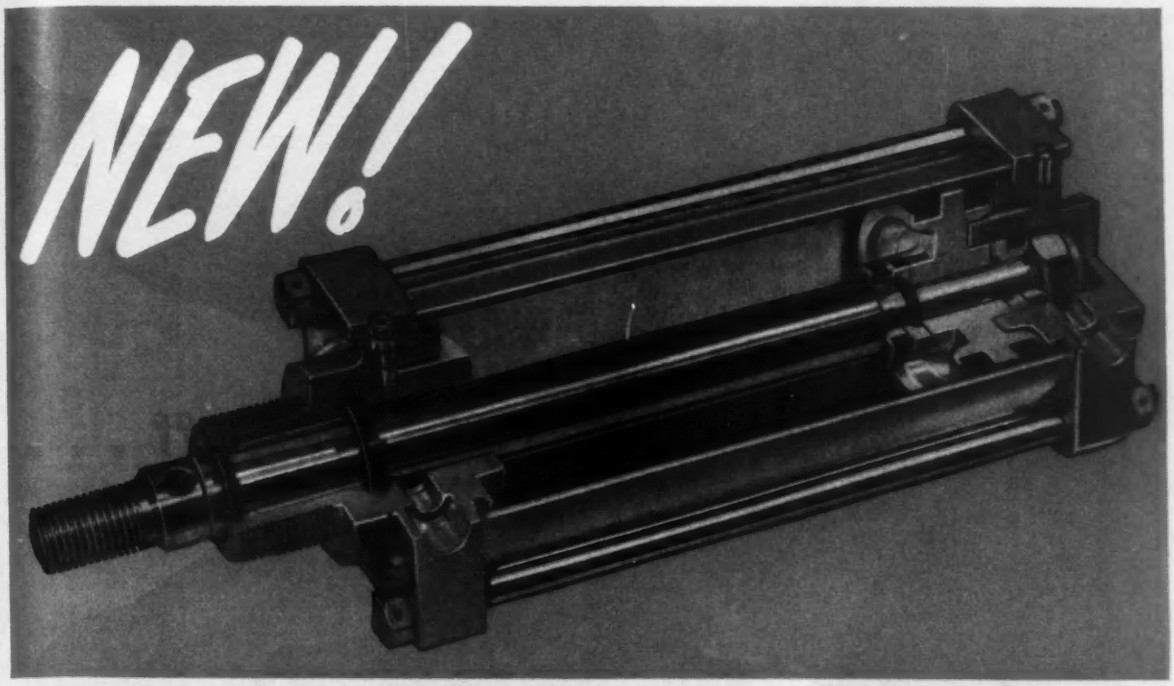
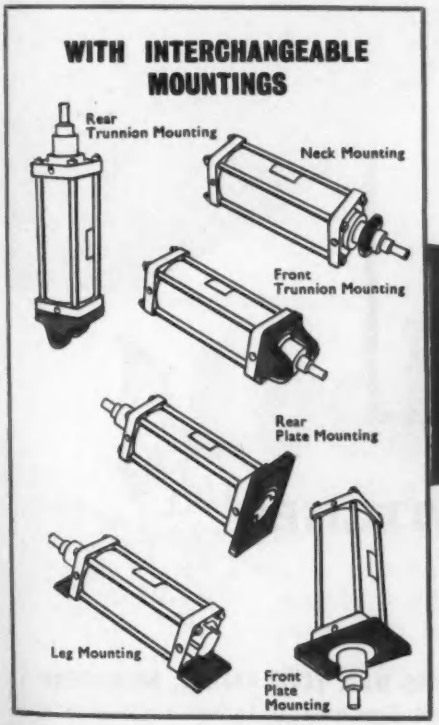


Schrader SQUARE-END AIR CYLINDERS

Cushioned or non-cushioned

These new Schrader square-end double-acting cylinders will meet a wide range of applications for holding, positioning or moving work or, with push, pull or lifting movements obviate many tiring manual operations. The cylinders have a standard neck-mounting but the square-end design provides for a variety of interchangeable mountings including leg, front or rear plate, front or rear trunnion.



Four bore sizes are available with standard piston strokes, cushioned or non-cushioned. The robust construction and new design features give safe, controlled, low-cost power for air pressures of 5 to 150 p.s.i. This range of Schrader Cylinders offers something really new in construction, performance and adaptability. Send the coupon today for full descriptive details and specifications.

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The New BURGESS V-4

* No larger than the average cuff-link
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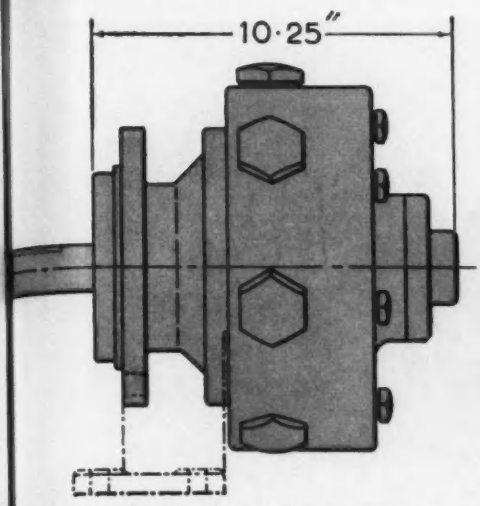

Pump is available for either flange or foot mounting.

Lockheed
hydraulic pumps

These Lockheed pumps have been expressly designed for use in industrial applications, where freedom from limitations of space and weight has enabled us to use a massive construction with generous ball and roller bearings.

As a result, the pumps may be expected to give a long, trouble-free life with maintenance of the original efficiency.

The "MERSEY" pump illustrated is available in capacities, at continuous rating, ranging from 3 up to 6½ gallons per minute at pressures up to 5000 p.s.i., depending on the volumes delivered. This variation in capacity is obtained within the same main construction by the use of interchangeable cylinder inserts of three alternative sizes.

While primarily intended for direct coupling to suitable electric motors, this unit, being of piston type, retains high efficiency at low speeds. The design not only incorporates all features necessary for long life under full load conditions, but has produced a unit in which ease of servicing and fitting replacement parts is outstanding.

Send for particulars of this and other hydraulic pumps in our range.

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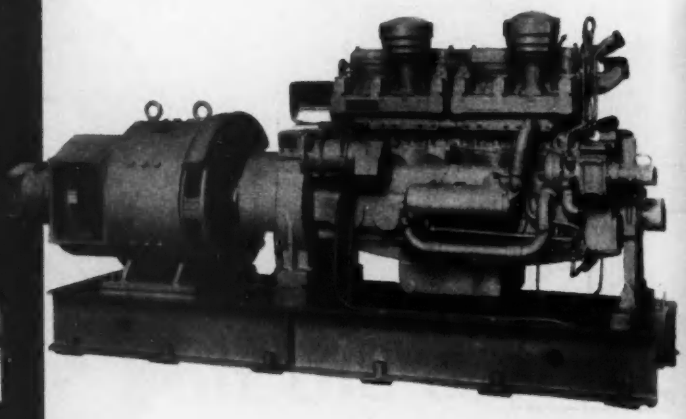

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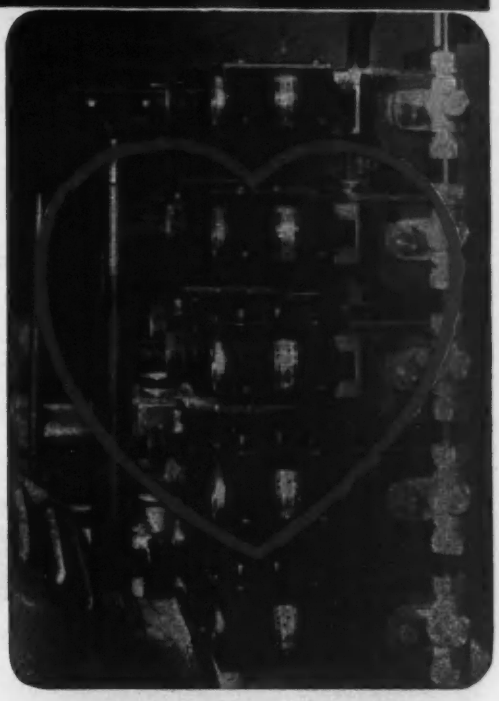
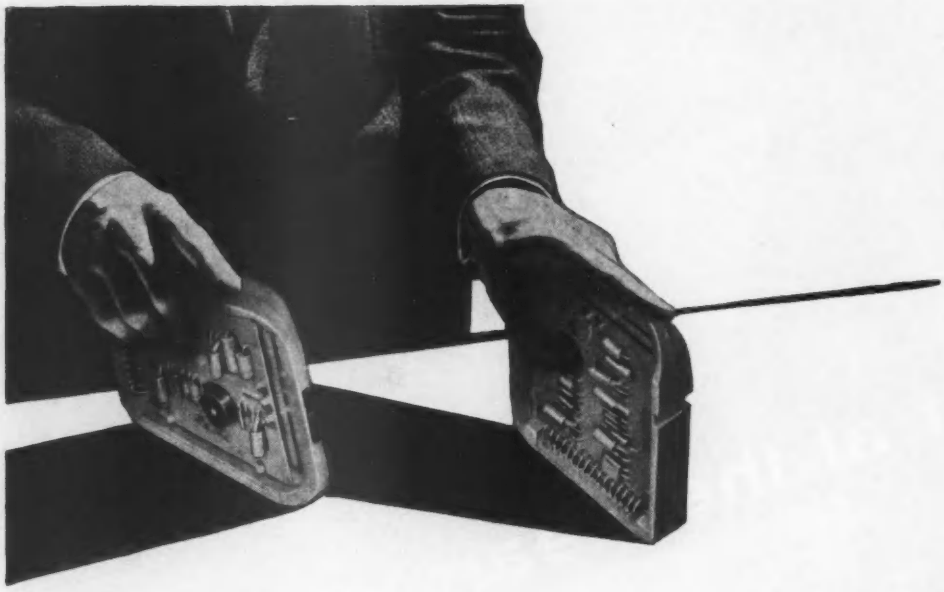


Bank of Westool Solenoids operating hydraulic valves. Photograph by courtesy of Towler Brothers Ltd, Leeds.

TIS. 138



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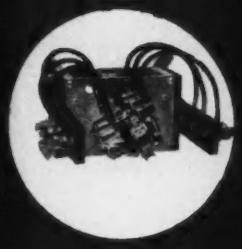

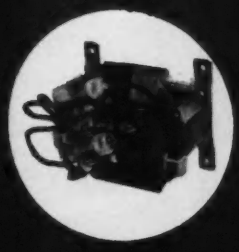

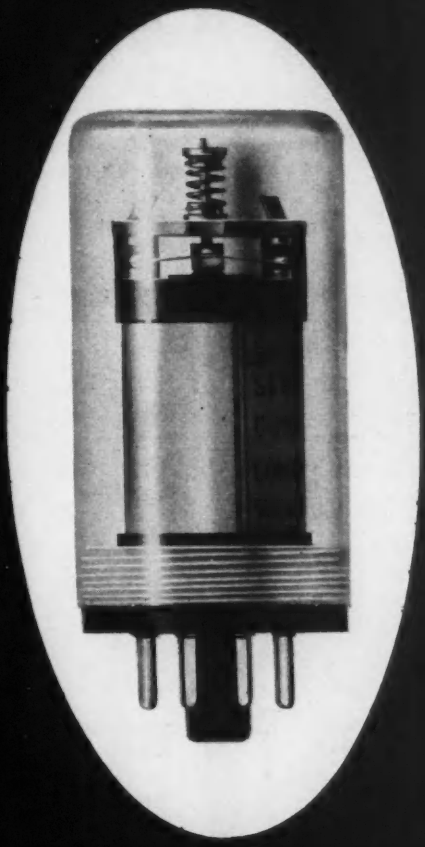

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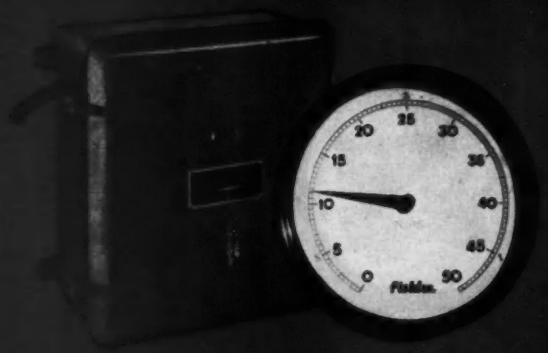

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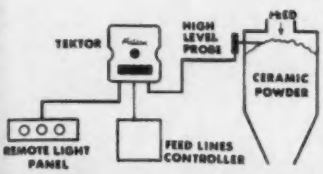

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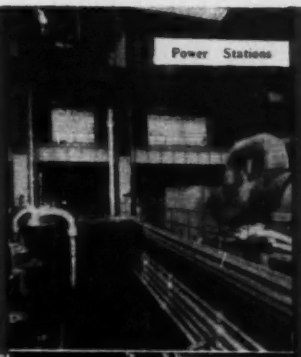

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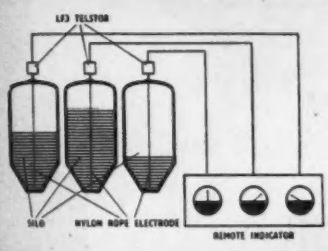

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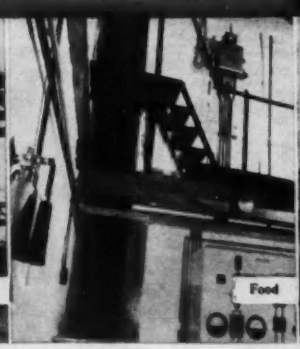

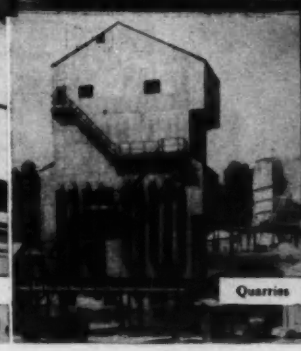

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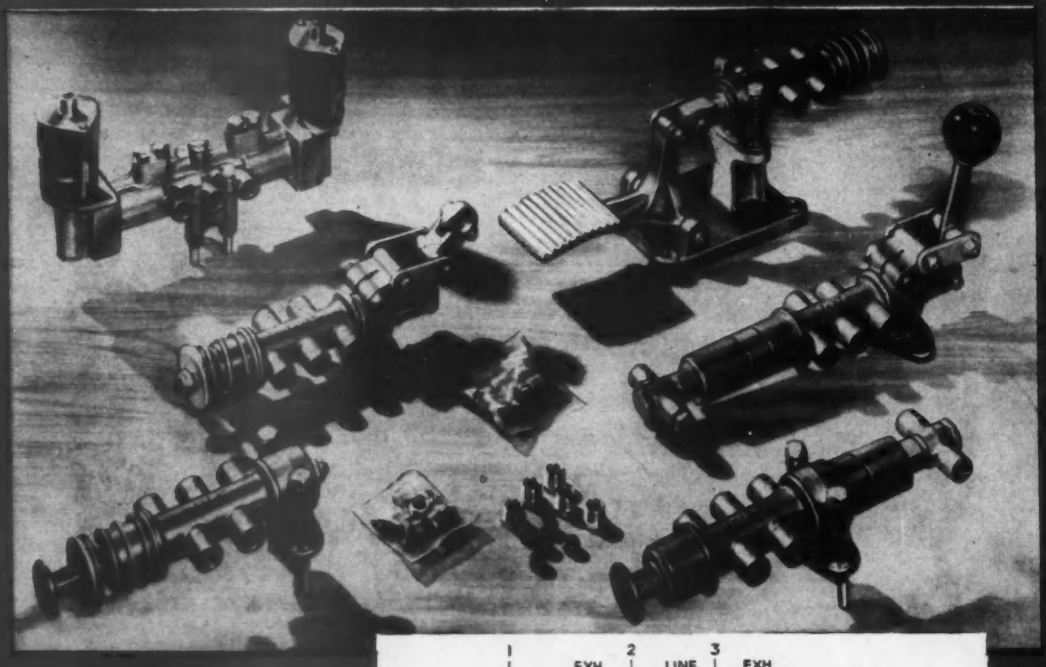

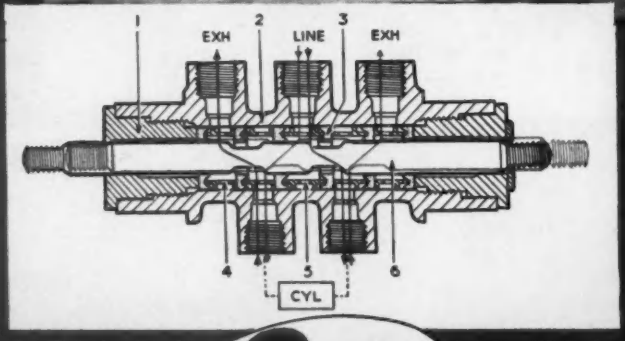

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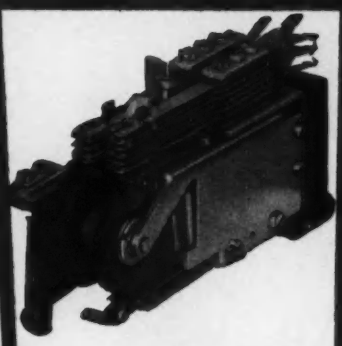
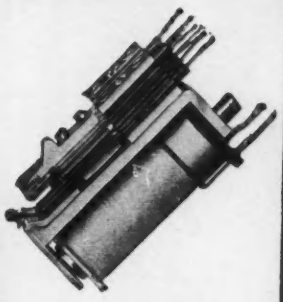


Ratchet Relay



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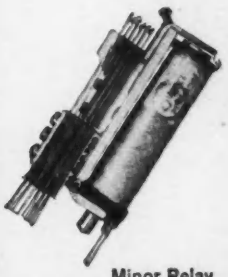

Minor Relay
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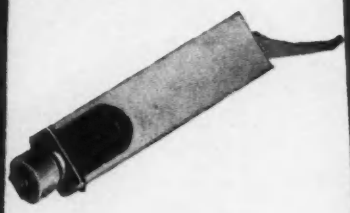
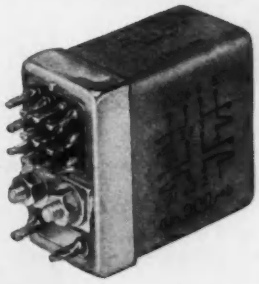


Tension Gauge



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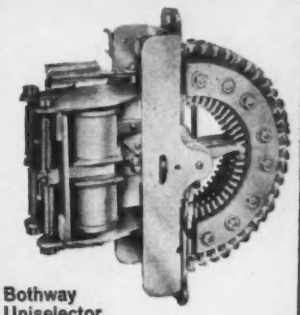

Bothway
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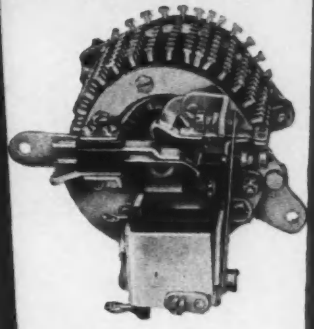

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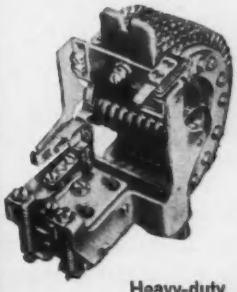

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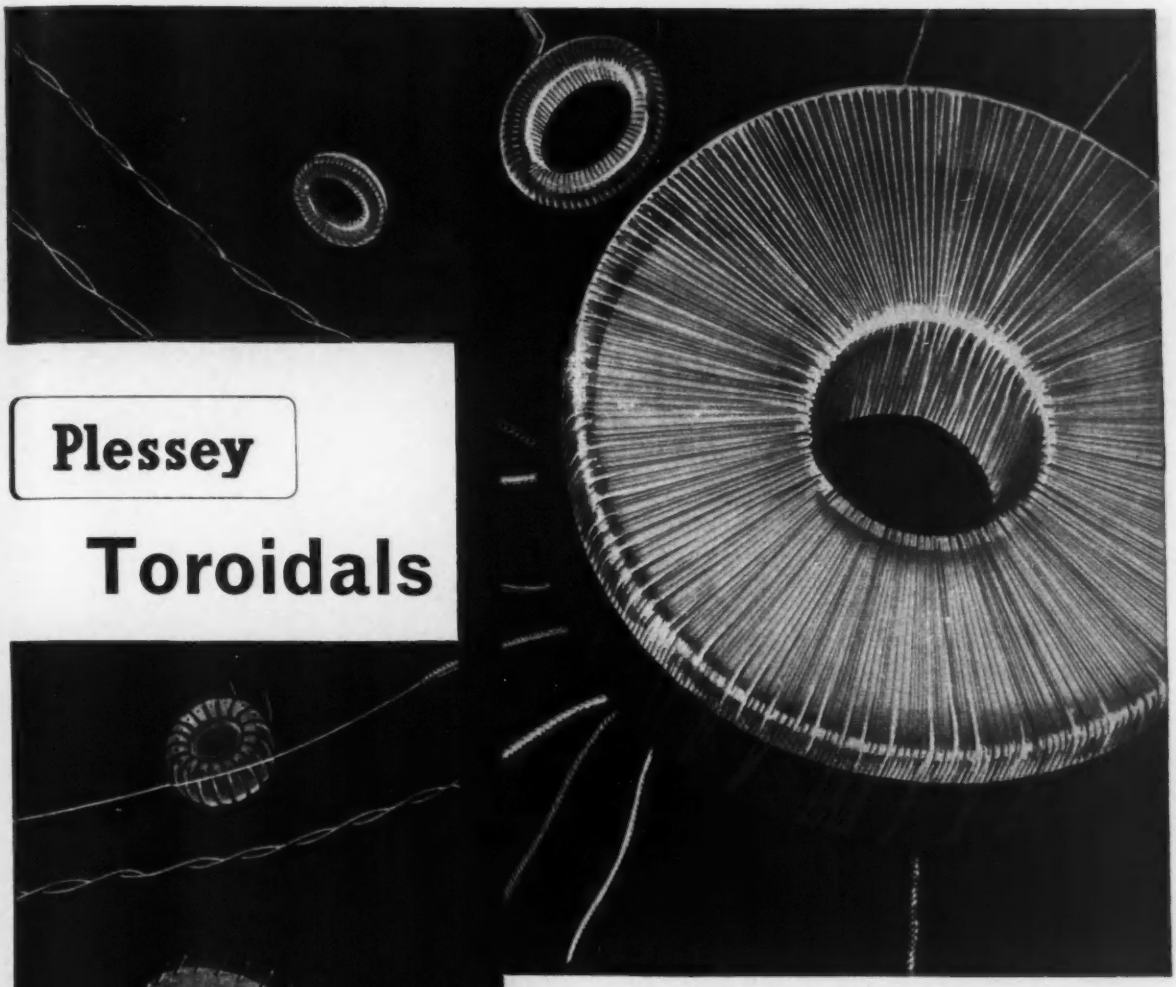

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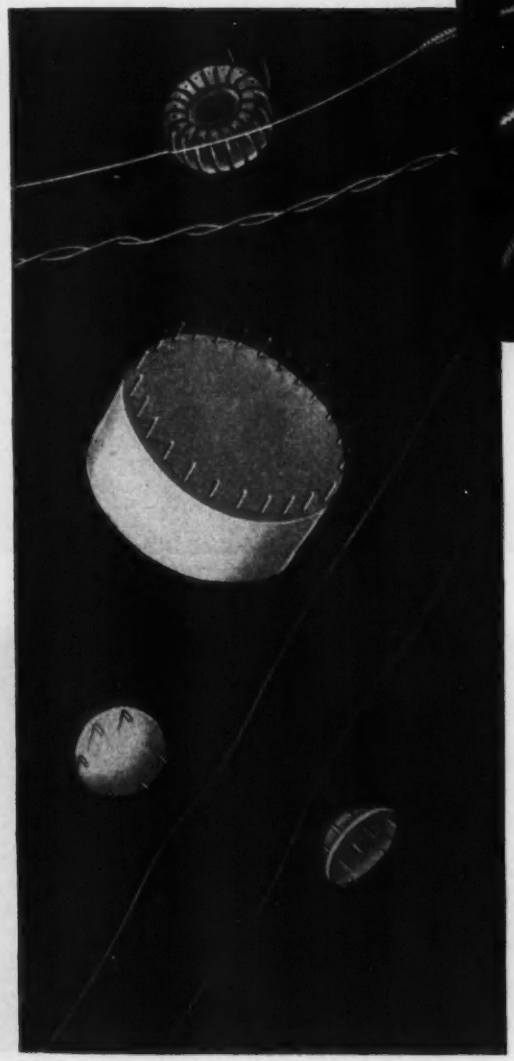

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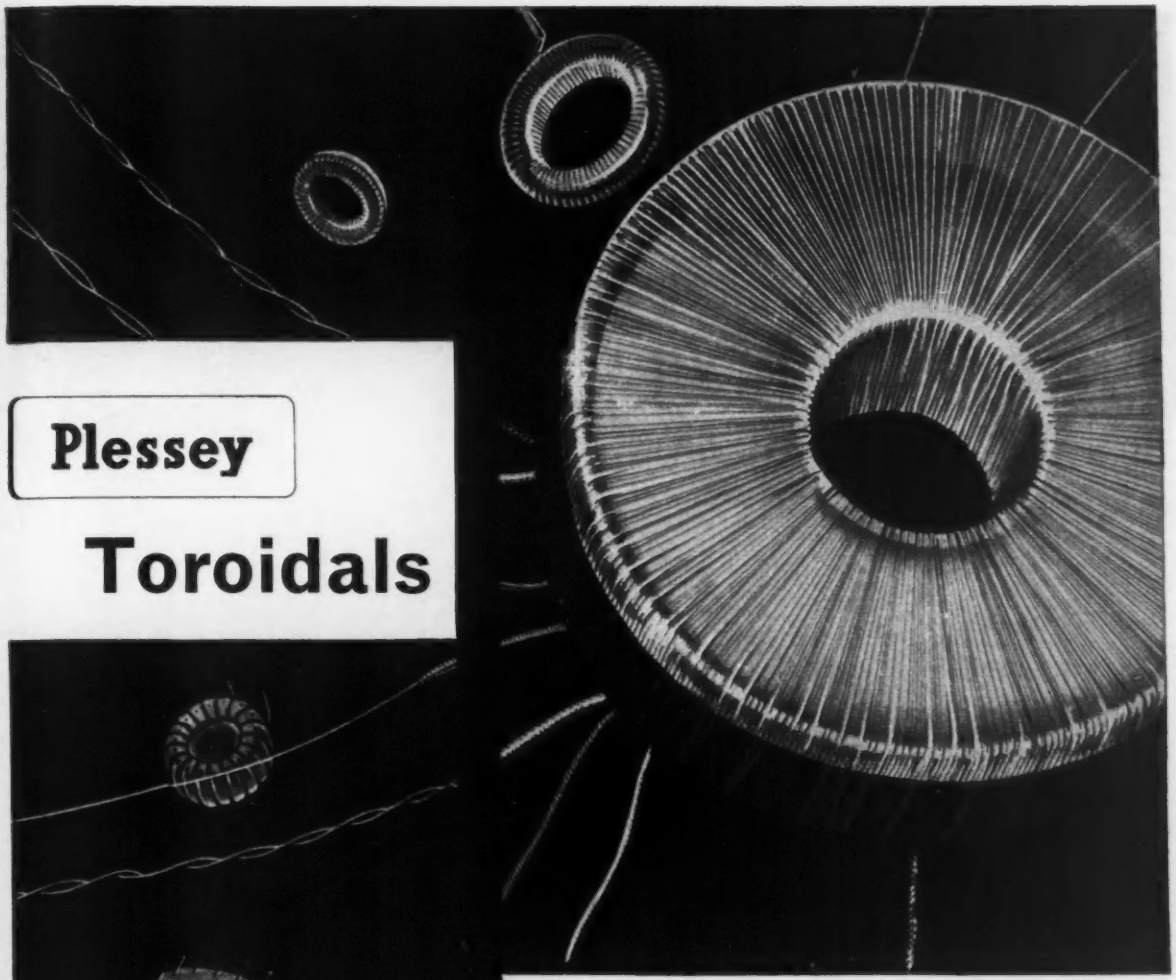

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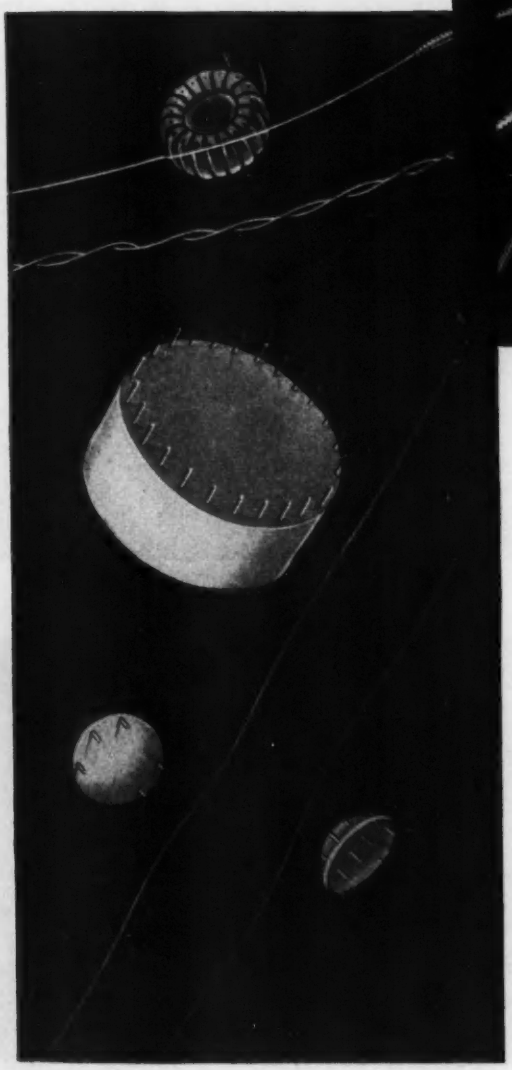
Toroidals



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Collector current	10	10	10	10	mA
Emitter-base voltage	0·5	0·5	0·5	0·5	Volts
Alpha cut-off frequency	30	30	100	120	Mc/s
Dissipation (free air 25°C)	120	120	120	120	mW
Collector-base capacitance	2	2	2	2	pF

DECEMBER 1960 VOL. 3 NO. 30 CONTROL

No weakness in numbers

SIR HERBERT MANZONI, President of the Institution of Civil Engineers, said recently that the engineering profession 'has suffered much from "fragmentation" or "splinter" groups in the past'. Sir Herbert deplores the fact that 'new organizations of specialist groups are continually being formed to provide facilities for meetings and discussions', because after a time these specialized groups tend to become qualifying bodies, with their own presidents, committees, secretariats and, of course, subscriptions. Since there are numbers of important people still advocating the formation of such 'splinter' groups, it is clear that not every engineer has become aware of the suffering diagnosed by Sir Herbert Manzoni. Nor will everybody take kindly to the cure prescribed by him. 'The ultimate aim', he says, 'should be that of one society of professional engineers whose corporate members should be Chartered Engineers. This would resolve the difficulties presented by the present multiplicity of titles which professional engineers have bestowed upon themselves during the past hundred years, and which have created such confusion in the minds of the public'. It is true that there has been much confusion in the English-speaking world over the term *engineer* and the aptness of the word *professional* in front of it, but that confusion can scarcely be blamed on the nucleation of engineers around particular centres of interest. While laymen are admittedly uncertain about the division of engineers into civil, mechanical, electrical and other categories, there is a much more melancholy muddle in the public mind over the distinction between artisans and scientific practitioners. The historic attempt to draw a clear line between these two was the founding of a 'professional' institution walled in by an entrance examination. Equally historic is the fact that a very great engineer was barred thereby, and a 'splinter' institution had to be formed for him and his like. The lesson was duly learned, and when a private Bill was put before Parliament in 1888, proposing that all entrants to the engineering professions must pass a qualifying examination, most of the institutions petitioned against it.

Sir Herbert Manzoni tells us that 'the professional education of engineers should be broadly the same up to a certain stage and that specialization should follow. Subsequent practical training should be organized and should be tested without exception before a professional qualification is awarded'. We agree, but we do not see it as a logical consequence that only one society should undertake the whole task. Suppose it did; then inevitably the special interests would have to be recognized as 'sections' or other fragmentations of the monolith, and we should be back where we were (except for the administration, and that is another story). Sir Herbert has a perfectly valid point about the universality of engineers' basic subject-matter, but is not this best met at college level? Only there is the unity of the fundamental principles a matter of zealous daily observation. In his after-life the student in most cases becomes so specialized that he comes to regard the members of 'other' engineering societies almost as members of different professions. Whether one considers this to be an unhappy situation or perfectly natural depends on one's temperament, but we like to believe that there is room for both broad-viewers and specialists in this variegated world, and we do not think that different specialists should be driven together against their will. Indeed, only a few months ago we were arguing the need for yet another 'splinter' group, an institution to satisfy the interests of the control engineer, and ours has been only one contribution to a continuing discussion on this very important topic.

We should very much like to agree with Sir Herbert. The notion of unity has always had deep philosophical appeal, and the fear of diversity is not entirely an irrational one. Yet we believe that proliferation of technological societies is bound to accompany the proliferation of technical studies. To guard against excessive compartmentalization there may well be call for a greater number of collaborative arrangements between the various institutions (perhaps along the lines already followed with the British Conference on Automation and Computation), and these could profitably lead to a broad conference of engineering organizations: but the possible administrative gains of such a development should not blind us to the essential differences between the specialized bodies. It is pure romantic sentiment to wish for a return to the less crowded past.

LETTERS to the EDITOR

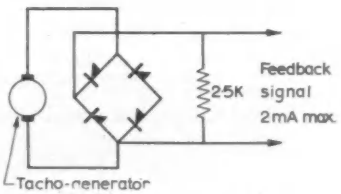
Problem of rectification

SIR: I am wondering whether you can kindly offer assistance to me for a particular technical problem:—

A bridge rectifier is required to operate in the main feedback of a servo-system so that feedback from a reversing D.C. tachogenerator, is always of one polarity. The servo-system is a speed regulator and operates over a 50 : 1 speed range; maximum tachogenerator output is 240 volts DC and loading is limited to 100 milliamps.

Arising out of this the rectifier arms must have a peak inverse voltage of say 300 or more, and rectify over a current range 100 milliamps down to 2 milliamps. Minimum feedback is about 5 volts so that the rectifier drop when passing 2 milliamps should not exceed say 1 volt. The rectifier would be mounted in a control panel and should give consistent operation for the normal temperature variations.

A sketch of the arrangement is shown below:



Incidentally an arrangement using Mullard OA5 rectifiers has already been tried and is workable but the disadvantages are that the peak inverse voltage is low and being germanium the rectifiers are liable to vary appreciably with temperature.

I would be most grateful for any assistance in this matter.

Rugby J. C. GOSLING

● *We will be glad to pass on any suggestions from readers.*—EDITOR

Fundamental difference

SIR: Mr. Stafford Beer is over-optimistic in feeling he and I can now agree.*

May I repeat that I have no wish to detract from the meat of his article† which triggered this correspondence, nor indeed from any of Mr. Beer's work in which he is so well-known.

I have no doubt that Wiener and McCulloch accept Mr. Beer's model as a cybernetic control system—a non-cybernetic control system would be a paradox.

A study of Mr. Beer's paper presented at the 1956 International Congress on Cybernetics reveals the origin of his misuse of the word "cybernetics". He states on page 30: "Operational Research deals with predictions, comparisons and decisions in man-machine systems, through scientific 'models' of their activity . . ." and, later on the same page, "Cybernetics deals with the *whole field* of communications and control in the animal and the machine. It is especially interested in analogies between their modes of functioning. Thus cybernetics is also concerned with models as defined". (My italics.)

It is important to appreciate that whilst cybernetics is concerned with models of the type Mr. Beer refers to, it is not *exclusively* so concerned, but remains concerned with the whole field.

Mr. Beer goes on to discuss a required model of the communication and control mechanisms of a viable man-machine system such as a factory, an administrative centre, or a mine, and he calls such a model a Cybernetic Analogue. He proceeds to describe the interplay of Operations-Research and Cybernetics in the activation, operation and interpretation of such a model, and develops his points to show that "Cybernetics, though it may include automation in its scope, is something wider and more responsible". He then refers to "the real nature of automation—which is cybernetic". Up to this point I agree with Mr. Beer, and I am sure that up to this point no one would quarrel with my earlier statement that every company is a "cybernetic company" in that it is controlled somehow.

It is after this point that Mr. Beer begins to use, unconsciously perhaps, a different definition of "cybernetics". The rigorous statements of the dividing line between control systems of different degrees of sophistication (which appear on page 37 of the paper) are causative definitions of two types of machine. The first Mr. Beer calls an automaton, and is a machine whose causal factors are deterministic. The second type of machine is one whose causal factors are probabilistic. The distinction is certainly clear, rigorous and useful but I quarrel with Mr. Beer because he uses the word "cybernetic" *to distinguish* the probabilistic machine. One cannot reconcile this use of "cybernetic" with Mr. Beer's earlier statement that "Cybernetics, *though it may include automation in its scope, is something wider*", nor can one reconcile it with the accepted definition of cybernetics as dealing with the *whole field* of communications and control, which must therefore include an automaton.

This is the root of our disagreement and it is an important one. It demonstrates clearly how Mr. Beer is applying the broader word to the narrower field.

In his last letter to you, Mr. Beer has misrepresented me. Certainly I called for a precise establishment of a dividing point if we are going to distinguish control systems of differing degrees of sophistication, but I cannot accept that the more sophisticated class can be properly described as "cybernetic" *in order to distinguish it* from simpler systems. A study of the works of W. Ross Ashby illustrates the enormous gulf between the broad (and, I suggest, correct) meaning he gives to the word and the narrow interpretation now given by Mr. Beer. If we are going to accept Mr. Beer's expressions "Cybernetic Company" and "Cybernetic Factory" with the meanings he gives to them, then we must re-define Cybernetics as the "science of control and communication, in the animal and the machine, insofar as such control systems are not wholly deterministic". I am more reluctant than is Mr. Beer to put words into the mouths of others, but I hardly think that Wiener would accept such an amended definition, whilst Ashby clearly states "Cybernetics deals with all forms of behaviour insofar as they are regular, or determinate, or reproducible" (An Introduction to Cybernetics, 1956).

Unfortunately this is not a matter on which we can merely agree to differ. There is a fundamental difference in usage of words.

JOHN B. RUDKIN

Bishop's Stortford, Herts.

*Letters, October, p. 84.—EDITOR.

†*The cybernetic company*, June, p. 95.—EDITOR.

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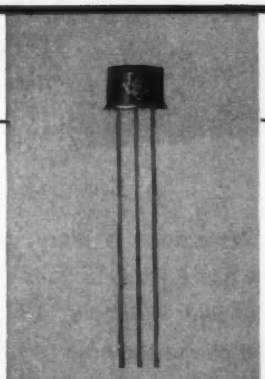
V_{CB} 60 V max	 ACTUAL SIZE	V_{CB} 25 V max
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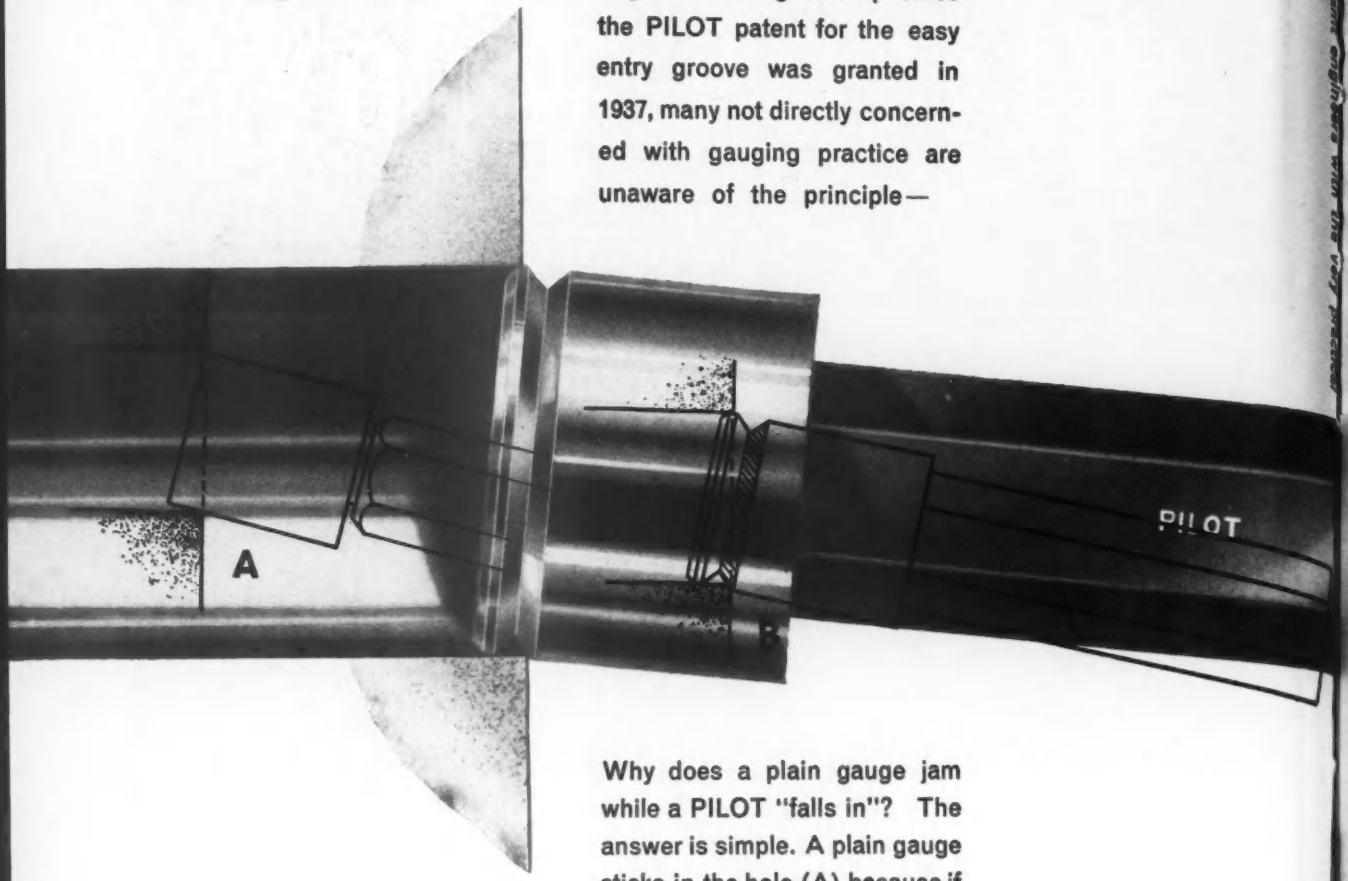
PILOT PRACTICALITIES - 4

Because a new generation of engineers has grown up since the PILOT patent for the easy entry groove was granted in 1937, many not directly concerned with gauging practice are unaware of the principle—



Why does a plain gauge jam while a PILOT "falls in"? The answer is simple. A plain gauge sticks in the hole (A) because if it is not square it jams across the hypotenuse of the triangle indicated by the dotted line. With the Pilot (B) if the gauge is not square then the chamfer of the groove (shaded dark) lifts the gauge into line with the hole and it "falls in". After 23 years the effectiveness of the Pilot lead still amazes engineers.

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VIEWPOINT

Dr R. A. Gregory, joint managing director of Midland Silicones, looks at the peculiar problems of . . .

CHEMISTRY AND CONTROL

The chemical industry operates a relatively few large-scale continuous processes and a multitude of smaller processes frequently of the batch or semi-continuous type. Many involve competing chemical reactions which give variable product yields even under carefully controlled laboratory conditions. Processes involving gas-liquid-solid mixtures usually defeat the chemical engineer's attempts to obtain strictly reproducible unit operations. The instrument manufacturer must not be too surprised therefore, if the chemical industry appears slow to adopt some of the newer techniques of instrumentation. The design of automatic controllers, especially when computers are involved, is well ahead of the mathematical understanding of many processes to which such techniques might otherwise be applied. Even if cost is ignored, it is easy to understand why so few large-scale chemical processes have been brought under fully-automatic control. Thus the instrument manufacturer must be prepared to help the chemical manufacturer to develop 'tricks' which will allow such things as computer-control to be applied to processes *before* their basic mathematics are understood.

Most chemical processes need but a small labour force, and process cycle-times are relatively long. The efficiency of chemical conversion of raw materials into finished products frequently lies in the range of 70–95%, especially for organic reactions. It is only in the simplest of chemical reactions that efficiencies of 98–99% are achieved. The chemical manufacturer can therefore better justify the use of automation as a means of improving product yield and quality, than as a means of saving time and labour. The control of process variables, combined with the continuous measurement of physical properties such as viscosity and refractive index, goes some way towards ensuring uniform product quality. However, the ultimate answer can only be obtained by replacing some of the work of the laboratory analyst by a system of continuous chemical analysis on the plant, including the use of spectrographic and chromatographic techniques. Speed in obtaining chemical, as opposed to physical, 'feedback' information is essential for successful process control.

The measurement of solids, and the control of plants which handle them, present far more difficult problems in instrumentation than the measurement and control of liquids and gases, although the instrument manufacturer must also be ready to accept the fact that many industrial liquids are in fact corrosive sludges at some stage. A wide range of such problems requires further investigation before many processes can be safely entrusted to instrument control.

However well they may be operated, all chemical processes are liable to emit dust and fume. Vibration and variable ambient temperatures are also common features, and inflammable vapours may be a further hazard. Rugged construction and ease of maintenance are, therefore, essential: unit construction of controllers, so that a faulty section may be replaced and the old one repaired away from dust and fume, is to be encouraged, despite greater initial cost. Unit construction also provides a partial answer to the acute shortage of trained instrument mechanics, and allows the use of fitters and electricians with some instrument training as maintenance men, thus reserving the totally inadequate nucleus of fully trained technicians for employment in the instrument shop.

The common hazard of inflammable vapours, and the frequent need for the use of continuously-variable flow-control valves in process lines, means that pneumatically-operated control systems will probably continue to be preferred to all-electric systems in open areas of many plants. On the other hand, chemical manufacturers must also be more prepared to concentrate control equipment in separate air-conditioned buildings than they have in the past.

Over-long deliveries are being quoted for even the simplest of instruments and spares. I should also like to suggest some improvements in design. Instruments should be waterproof—not just weatherproof—so they they may be hosed down; specification plates should be non-corrodible and attached to the instrument body, not to an interchangeable lid; dimensional drawings should give the required angle of door openings; outlet connector threads should be standardized; alternative materials of construction should be provided.

There is an old-fashioned attitude towards automation in the British chemical industry today; the instrument manufacturer can help to dispel doubt by recognizing its peculiar needs.

R. A. Gregory

PART 1

Although costly automatic techniques are little used in the textile industry at present, instrumentation and control are playing an increasingly important part in the search for improved quality and higher productivity

Controlling the production of nylon yarn

by **R. N. ALDRICH-SMITH**, M.SC., F.INST.P., A.R.C.S., D.I.C.
British Nylon Spinners Ltd

IN THE TEXTILE INDUSTRY GENERALLY, THE FORMATION and processing of yarn is characterized by the large numbers of production units known as 'spindles'. These units, grouped into multi-spindle machines, are usually of relatively low productivity and require frequent manual 'restringing', 'doffing', etc. A direct contrast is thus apparent with the automobile industry, for instance, where the mechanization of a few production lines, by means of conveyors and transfer machines, has reached an advanced state of development.

At first sight, therefore, it would appear that yarn production processes offer little scope for the exploitation of the relatively expensive automation techniques, and this may be true of conventional yarn processing for some time to come. However, in the normal course of healthy competition, and the constant search for improved quality and higher productivity, it is becoming better appreciated that instrumentation, at least, can play an increasingly important and rewarding part both in the control of yarn quality and process machinery, as well as in the ancillary services. This is true particularly in the case of nylon yarn production in which a wide range of chemical, physical and engineering effort is devoted to the maintenance and improvement of both quality and productivity.

Two of the early stages in yarn manufacture from nylon flake are peculiar to several other synthetic fibre forming materials. These are the melt extrusion of a continuous filamentary intermediate, and the drawing of the latter to form a textile yarn. The fact that these stages confer a measure of inherent uniformity on the product means that high standards of product quality can be set. Quality in yarn production means the achievement of long manufacturing runs producing acceptable levels and limits for each of the many relevant chemical and physical characteristics at all stages of processing.

Leaving purely chemical tests aside, the routine sampling and testing for such properties as whiteness, moisture and impurity content of the raw material, well repay this effort by ensuring that expensive processing is not carried out on sub-standard material. Thereafter, extrusion variables are closely monitored against conditions which may give rise to off-standard product characteristics, which cannot be corrected during the later stages of processing. Extrusion temperatures are particularly critical, whilst the linear density and moisture content of the resulting filaments are typical of the variables requiring unusually close control. At the drawing stage, the main concern is with the continuity and

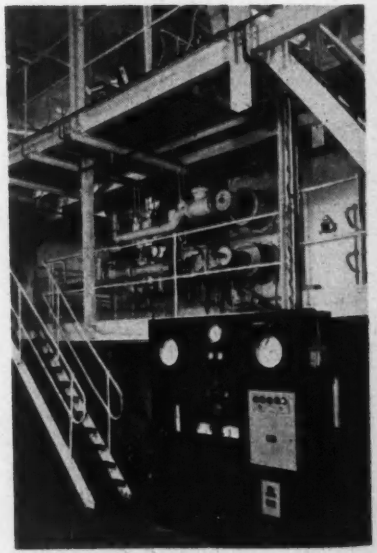


Fig. 1 Vaporizer for heat transfer medium with its control cubicle

uniformity of the draw throughout extremely long lengths of yarn. Also, variations in ambient conditions (humidity and temperature) must be limited to avoid not only the devastating effects of static electrification, but also the occurrence of tight or loose sections in the package build. Beyond the drawing stage, processing consists of carrying out such operations as 'bulking', warping (for weaving or warp knitting) and heat-setting, before final inspection, packing and despatch to the customer.

To ensure adequate control of these typical variables, some measurement and control techniques peculiar to nylon yarn production have been evolved. However, much use is also made of commercially-available equipment, both for yarn testing and in the routine instrumentation problems common to most process industries.

Extrusion temperature control and monitoring

The nylon flake (polyhexamethylene adipamide) is heated to a temperature around 300°C before extrusion takes place, and this is done in relatively small quantities in a large number of melter units fitted with finned grids and jackets. The latter are supplied with a vaporized heat-transfer medium which has a low vapour pressure at elevated temperatures, combined with a relatively high latent heat of vaporization. The saturated vapour is generated centrally in an automatically controlled, gas-fired tube boiler rated at 11,000,000 Btu/h (Fig. 1) and is piped to all the melter units, the condensate flowing back to the boiler for re-evaporation. The control line diagram of a typical boiler is shown in Fig. 2.

If the vapour pressure in the heaters is arranged to be uniform throughout the plant, then the latent heat is released at a uniform temperature. The holding temperature of the molten polymer is critical, for it determines the melt viscosity and rate of chemical degradation, and great care has to be taken in the control of vapour pressure at the boiler. The required pressure is such that barometric compensation must be made since temperature is a function of absolute vapour pressure only, and normal barometric variations would otherwise result in prohibitive long-term variations. Fig. 3 (inner trace) shows a typical chart of vapour pressure control where each sub-division represents 0·5 lbf/in². The long-term temperature variation corresponding to the recorded pressure variation is well within ± 0·5 degC, as seen from the outer trace of Fig. 3, where each sub-division represents 1 degC. Bearing in mind that pressure equilibrium takes place quickly throughout the system, the advantage of controlling boiler pressure, rather than temperature, becomes apparent. Temperature irregularities due to the accumulation of inert gases are mini-

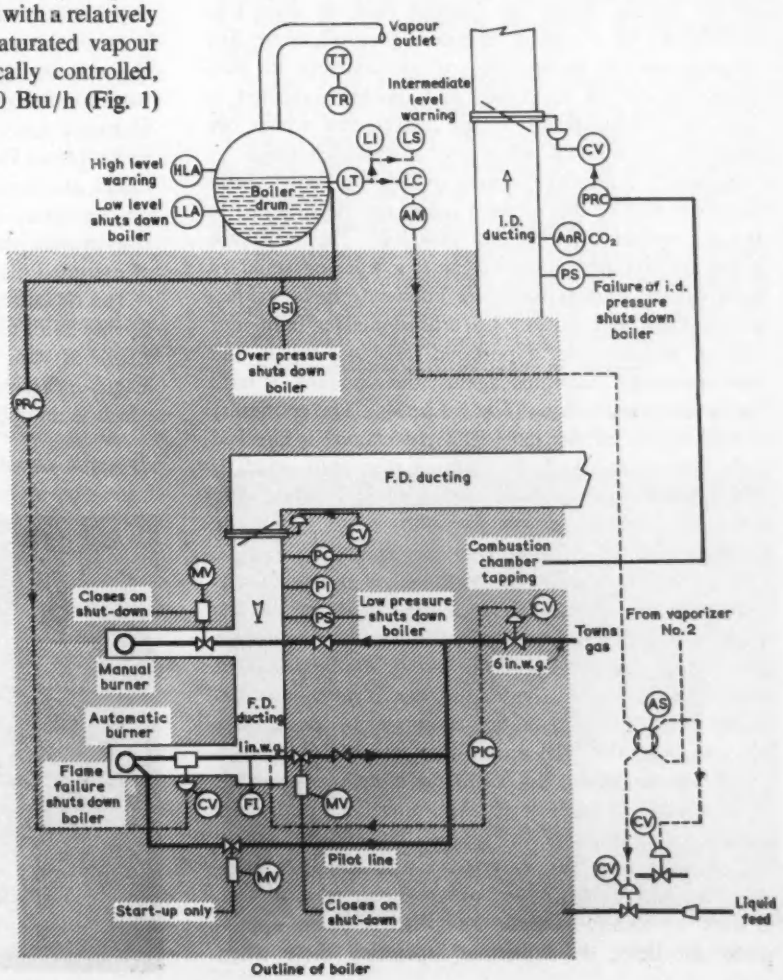


Fig. 2 Control line diagram of vaporizer for heat transfer medium. Code: PRC, pressure recorder controller; PIC, pressure indicator controller; AnR, CO_2 recorder; TT, temperature transmitter; TR, temperature recorder; LT, level transmitter; LC, level controller; LI, level indicator; PC, pressure controller; MV, magnetic valve; CV, control valve; FI, flow indicator; PI, pressure indicator; AS, air switch; PS, pressure switch; HLA, high level alarm; LLA, low level alarm; LS, level switch; AM, auto-manual station

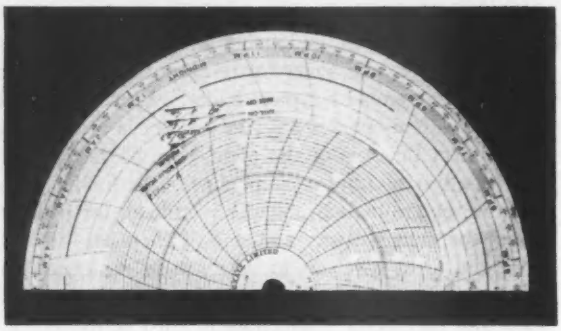


Fig. 3 Chart sections giving vapour pressure (inner trace) and plant temperature (outer trace) records. The long-term temperature variation under vapour pressure control is well within 0·5 degC

mized by venting off these gases at the high points in the system. By suitable sizing of the distribution pipework, the pressure drops due to flow are such that a temperature drop of no more than 0·5 degC occurs between the distribution points nearest and farthest from the boiler.

Thus melt temperatures should be uniform over the whole plant within ± 1 degC. The problem of checking that this is so at all times, and that no pipe or heater restrictions develop, is met by the extensive deployment of carefully-trimmed resistance bulbs at strategic parts of the system. These are coupled back by three-lead connexions to a central monitoring panel where any temperature can be recorded or, alternatively, all temperatures can be accurately and quickly indicated in turn by self-balancing bridge instruments which are graduated in 0·2 degC steps over a restricted range.

Standard resistances, corresponding to temperatures on either side of the working point, can be switched to the instrument for checking purposes. The resistance bulbs are trimmed initially against a working standard bulb whose characteristics are known from occasional comparisons with an N.P.L.-certified master bulb. For ease of maintenance, a portable resistance-bridge and bulb assembly, calibrated against the standard, is used for the routine checking of bulbs on site. The continuity and resistance of the three-lead connexions is checked with a portable standard-resistance box, into which is plugged the bulb end of the three-lead cable. The error accumulation in this procedure is such that the probable error in any temperature check is ± 0·25 degC.

The other boiler control features are fairly conventional, but the control of level and the safety circuits merit brief mention. Owing to the fact that load changes are normally neither large nor rapid, a single-element level controller is adequate, and this comprises a displacer float system operating a pneumatic transmitter via a torque tube. The transmitted signal is piped to a panel-mounted level indicator and a bellows-operated limit switch, as well as to the controller. With four control valves, three boilers (one a stand-by) can supply two separate heat-transfer systems with adequate flexibility for boiler change-over or valve break-down. This is done by locally-mounted air switches in the appropriate air lines, the boilerman operating these when manipulating the feed stop valves. A typical installation of feed valves is shown in Fig. 4.

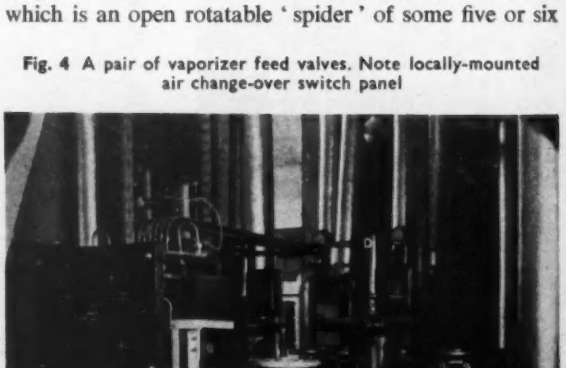
The safety circuit is maintained by three switch-contacts, controlled respectively by the flame-failure detector, excess-pressure controller and the level limit switch, any one of which on reaching the appropriate condition causes its contacts to open. This results in the de-energization of a three-way solenoid valve in the line to the air motor of the main gas valve, relieving the diaphragm pressure to atmosphere and thus shutting down the boiler.

Linear density control

The weight per unit length of a yarn expressed in grams per 9000 metres is known as the yarn 'denier', and this is a fundamental characteristic of first importance. For a yarn of nominal denier, both the long- and short-term denier variations are closely limited by commercial requirements. As stated earlier, the method of extrusion imparts considerable uniformity to the material in this respect. This arises from the use of high-pressure metering pumps for dispensing the molten polymer through the small holes in a die or spinneret (Fig. 5). These pumps are driven by the same motor as that used to drive the winding mechanism. The latter consists of a surface drive to the take-up cylinder giving constant linear wind-up speed throughout the build on the cylinder. However, several faults which affect uniformity of the filament but are not visually apparent at extrusion, can occur. Internal damage to the pump or a partially-blocked spinneret hole, are examples of such faults, and these necessitate frequent checks to be made on the denier in order to ensure uniform quality. For convenience, these checks are made soon after a 'cake' of extruded filaments has been formed.

The time-honoured direct method of measuring linear density in all textile yarn production, is to take a known length of yarn and weigh the skein so produced. The length measurement is made on a wrap reel (Fig. 6), which is an open rotatable 'spider' of some five or six

Fig. 4 A pair of vaporizer feed valves. Note locally-mounted air change-over switch panel



'swifts' measuring exactly one metre in circumference and accommodating between four and 24 threadlines according to the size of the reel. A simple traverse device layers the yarn on the swifts and, on either cutting the completed wraps or collapsing one of the spiders, the skein so formed can easily be removed. A refinement used for quick and accurate length measurement, is to drive from the reel a revolution counter which can be preset to the required number of revolutions. When this is reached, a pair of contacts is broken interrupting the current in the no-volts coil in the starter, thus de-energizing the driving motor and applying a brake. On larger reels, a lever-operated clutch uncouples the reel from the drive. As two operators are employed on such machines, two start buttons, wired in series and spaced along the machine, are fitted for safety reasons.

For the weighing operation to be practicable under shop floor conditions, a special-purpose balance employing damped analytical-balance principles was designed. This is incorporated in a sheet metal case, the

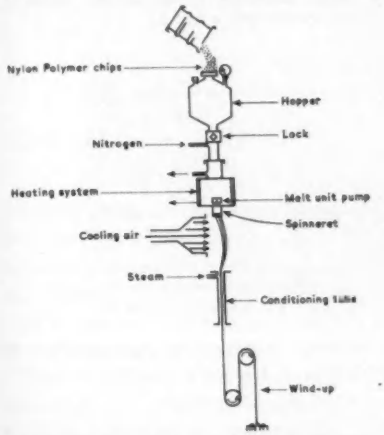


Fig. 5 The basic extrusion process

only normal access to which is via a small sliding door, opening on to the single pan, and just large enough for the skein to be conveniently placed in the pan. The action of opening the door operates a beam-arresting cam so that the door must again be closed before the beam is released, thus avoiding the effect of draughts. A direct-reading illuminated scale is graduated either in denier deviation from a nominal, or in actual denier over a restricted range. The nominal denier, or denier range, may be altered by the addition of special rider weights on to the beam. This is done by turning a detachable knob so that the appropriate denier appears in a small window on the rider arm cam box. A single weighing operation, including reading to $\pm \frac{1}{2}\%$ accuracy, can be performed in less than 10 s.

This method of testing, combined with a suitable sampling technique, has been satisfactory for production control but a more sophisticated method giving higher quality levels and greater working efficiency is needed.

Just as it is often desirable to analyse continuously a processed fluid in a pipeline, so it is equally desirable to be able to make denier checks on the threadline as it is being extruded. This is done by allowing the thread-

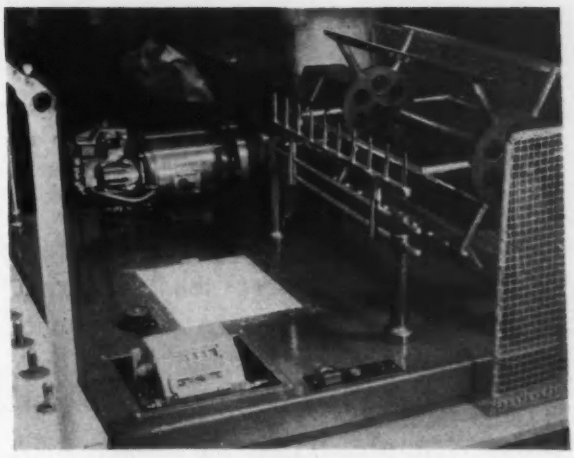


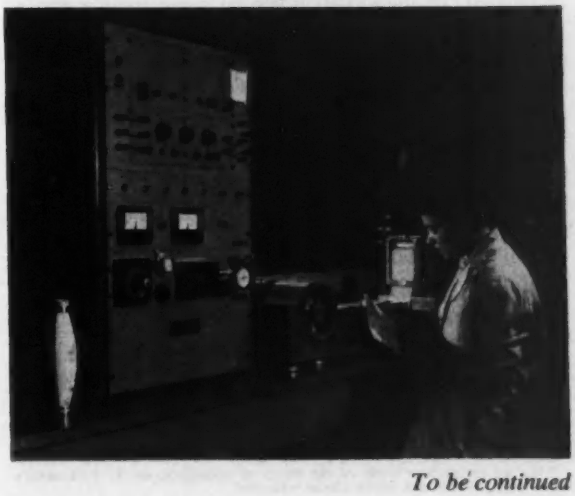
Fig. 6 A ten-position wrap reel fitted with an electromagnetic brake and preset counter

line to run between the electrodes of a specially-designed electrical capacitor, the volume of the threadline between the plates altering the capacitance. Variations in capacitance thus reflect instantaneous denier changes and, by suitable circuit design, long- and short-term denier variations may be recorded or integrated. The inclusion of limit switches on the servo-driven pen recorder, gives immediate warning of off-standard denier (*2, 3*).

A test-room instrument (*4*) operating on the same principle has also been designed for use on small samples of drawn yarn (Fig. 7). The sample bobbin having been threaded through this instrument to the drum wind-up mechanism, the test cycle is automatically programmed and the denier recorded in analogue form.

This instrument has long-term stability, and high sensitivity to small capacitance changes in the presence of a standing capacitance. A change of 1% in denier corresponds to a capacitance change of less than 0·001 $\mu\mu$F at an inter-electrode capacitance of 10 $\mu\mu$F.

Fig. 7 This capacitance denier test instrument, for small samples, provides an automatic test cycle and records denier in analogue form



To be continued

A well-known Soviet control engineer discusses the connexion between invariance theory and methods of investigating the 'reliability' of measuring devices

New methods of control-system investigation

by **A. G. IVAKHNENKO**
Ukrainian Academy of Sciences, Kiev

TO UNDERSTAND THE MAIN TOPIC OF THIS ARTICLE IT IS necessary to recollect what the theory of invariance is (*1, 2, 3*)*. By 'conditions of invariance' we mean those conditions which, applied to the coefficients of the system dynamic equation and to the main disturbances, may cause the error of the system to be completely eliminated, or minimized down to some small value ε. Initial conditions are zero. The conditions of invariance are very different, as shown in the table opposite.

To satisfy conditions **2a** and **3a** we have to use loops closed by feedback *from outputs*. These conditions are valid for all disturbances, but only error-minimization down to a small value ε is possible. Only separate components of the error may be overcompensated. For example, we can get negative reset in a two-looped system having enough stability and stiffness. So these conditions can be regarded as the *conditions of incomplete or non-absolute invariance*.

To satisfy conditions **2b, 3b** and **4** we have to use open loops with feedforward links *from disturbances*. These conditions are valid only for disturbances which are measured, but we can easily get partial compensation or complete compensation or overcompensation of the error. So we call these conditions the '*conditions of complete or absolute invariance*'.

The most nearly perfect systems are the combined ones†, where the feedbacks are adjusted by the rules of compromise setting, and *besides* by the conditions of non-absolute invariance **2a** and **3a**; but the feedforward links are adjusted by integral criteria or by conditions of absolute invariance **2b, 3b** and **4**.

For example, in a third-order system where

$$(p^3+a_2p^2+a_1p+a_0)\varphi = \lambda,$$

we can use non-dimensional times

$$T = \omega_0 t, \quad \omega_0 = \sqrt[3]{a_0}, \quad p = \frac{d}{dt}, \quad D = \frac{d}{dT}.$$

Then $$(D^3+xD^2+yD+1)\varphi = \lambda.$$

For the process of adjustment we can keep the dimensionless Vyshnegradsky (stability) parameters constant

Fig. 1 Influence of frequency (ω_0) change upon transient and frequency response (with invariable dimensionless 'Vyshnegradsky' parameters x and y)

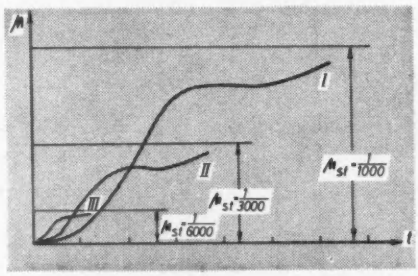


Fig 1a Transient responses according to equation $[1 + Y_{p\mu}(p)]\mu = [1 + n(p)Y_2(p) + Y_1(p)Y_2(p)m(p)]\mu = 0$ or $(D^3 + xD^2 + yD + 1)\mu = [1]$

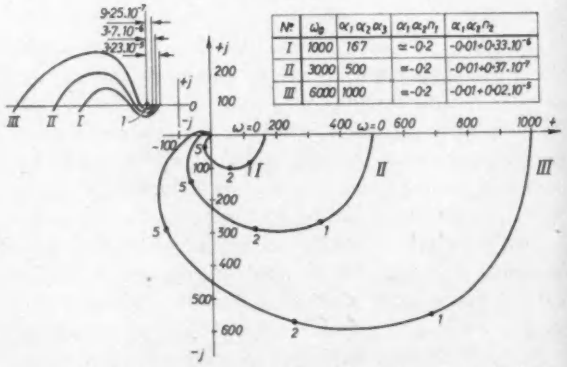
with

$$x = \frac{\tau_1\tau_2+\tau_2\tau_3+\tau_1\tau_3+\alpha_1\alpha_2n_1\tau_3+\alpha_1\alpha_2n_2}{\omega_0(\tau_1\tau_2\tau_3+\alpha_1\alpha_2n_2\tau_3)} \qquad y = \frac{\tau_1+\tau_2+\tau_3+\alpha_1\alpha_2n_1}{\omega_0^2(\tau_1\tau_2\tau_3+\alpha_1\alpha_2n_2\tau_3)};$$

$$\omega_0 = \left(\frac{1+\alpha_1\alpha_2\alpha_3}{\tau_1\tau_2\tau_3+\alpha_1\alpha_2n_2\tau_3}\right)^{\frac{1}{3}}; \quad \tau_1=\tau_2=0{\cdot}1 \text{ sec}; \quad \tau_3=0{\cdot}5 \text{ sec}; \quad m(p)=1;$$

$$n(p)=n_1p+n_2p^2; \quad Y_1(p)=\frac{\alpha_3}{\tau_3p+1}; \quad Y_2(p)=\frac{\alpha_1\alpha_2}{(\tau_1p+1)(\tau_2p+1)};$$

μ_{st} = steady error



№	ω_0	$\alpha_1\alpha_2\alpha_3$	$\alpha_1\alpha_2\gamma_1$	$\alpha_1\alpha_2\gamma_2$
I	1000	167	≈-0·2	-0·01+0·33.10⁻⁶
II	3000	500	≈-0·2	-0·01+0·37.10⁻⁶
III	6000	1000	≈-0·2	-0·01+0·02.10⁻⁶

Fig. 1b Polar plot of frequency response $Y_{p\mu}(j\omega) = n(j\omega)Y_2(j\omega) + Y_1(j\omega)Y_2(j\omega)m(p)$

* For an introductory study of the theory of invariance, see L. Finkelstein's article on p. 96 ff of last month's issue.—EDITOR.

† I.E. combining feedback with feedforward.—EDITOR.

System dynamics equation $a_s(p)\Phi = b_s(p)L_1 + b_s''(p)L_2$ where $p = \frac{d}{dt}$

N	FORMS OF INVARIANCE CONDITION		FORMS IN WHICH THE DISTURBANCES HAVE TO BE GIVEN	PART OF ERROR ELIMINATED	MEANS OF REALIZATION
1	$L_1(t) = 0,\ L_2(t) = 0$ (1)		Of no practical importance		
2	$\frac{b_s(p)}{a_s(p)} = 0$	$\frac{1}{a_s(p)} \to 0$ (2a)	In any form (for non-linear systems limited by acceleration)	The errors caused by all disturbances (including changes of parameters) are minimized. Non-absolute invariance	Rigid multi-loop conditional-stability systems, having 'beak-like' frequency characteristic. Operational feedback for servo-mechanisms
		$b_s(p) = 0$ $b_s''(p) = 0$ (2b)	The same	Total error caused by disturbances L_1 and L_2 is eliminated. Absolute invariance	Control by disturbances and their time derivatives
3	$\frac{b_s(p)}{a_s(p)} L(t) = 0$	$\frac{1}{a_s(p)} L_1(t) = 0$ (3a)	The common form, in symbols	Steady-state component only, caused by all disturbances	Integral control (after N. Minorsky and V. Kulebakin)
		$b_s(p)L_1(t) = 0$ (3b)	The same	Steady-state component caused by only one disturbance L_1	Control by disturbances and their time derivatives
4	$b_s(p)L_1(t) + b_s''(p)L_2(t) = 0$ (4)		In numerical form	Total error caused by disturbance L_1	Displacement or forcing device and artificial changing of reference of program systems

while the frequency increases:

$$x = const,\ y = const,\ \omega_0 \to \infty .$$

All coefficients of the characteristic (dimensional) equation will increase continuously. This means that the condition of non-absolute invariance, **2a**, will be satisfied as a limit.

The changes of the frequency response and the transients are shown in Fig. 1.

For every value of frequency ω_0 we find definite values of the inherent feedback coefficients: $n(p) = n_0 + n_1 p + n_2 p^2 + \ldots$ and gain $\alpha = \alpha_1\alpha_2$. The higher the gain, the nearer the system to absolute invariance. But we can increase the gain without change in the stability and stiffness of the given system, until the practical fluctuations of the coefficients $n_0\ n_1\ n_2$ are not too big and do not cause noticeable changes in the values of the dimensionless parameters x and y. Because of the increased gain the influence of these fluctuations becomes bigger and bigger, and the demands on the reliability* of amplifiers $n_0\ n_1\ n_2$ continuously increases. Therefore we must come to a stop somewhere.

We have to divide the work of the complete elimination of the error between the inherent feedback $n(p) = n_0 + n_1 p + n_2 p^2 + \ldots$ and the feedforward link $l(p) = l_0 + l_1 p + l_2 p^2 + \ldots$. So we have come again to *the idea of combined control.*

We have to strive to eliminate the bigger part of error by feedback because it eliminates the errors caused by *all* disturbances, while feedforward deals only with one of them.

The question arises: where must we stop? How are we to calculate the optimal limit to the use of inherent feedback? There are no adequate methods in present control theory to answer this question. Only the first steps in this direction were made in (*4*) and (*5*). It was shown there that to solve the problem we have to use the method of investigating measuring-device reliability, with some alterations, taking into account the specific features of control systems.

The theory of measuring-device reliability helps us to clarify the optimal limit on the use of the non-absolute invariance conditions **2a** in combined systems.

Two methods of reliability investigation are known: (a) the method of relative-error definition, and (b) the method of absolute-error definition. The former method we have to use when the system under investigation consists of a.c. amplifiers, i.e. of elements having *no* zero drift. The latter method we have to use when the system consists of d.c. amplifiers, i.e. of elements *having* zero drift.

As yet we have no methods available to investigate systems using d.c. and a.c. amplifiers simultaneously. These methods may be a subject for further research.

Investigation of single-loop system by relative-error definition

The scheme of the system under investigation is shown in Fig. 2. The linear equations of the elements are: control law $\Sigma = -M + \psi$; amplifier $\Phi = \alpha_{01} + \alpha_1\Sigma$; process $M = -\alpha_{02} - \alpha_2\Phi$ where: α_{10} and α_1 are the drift and gain of the direct element, α_{20} and α_2 are the drift and gain of the feedback element.

The equation of the system as a whole is

$$\Phi = \alpha_{0c} + \alpha_c\psi,$$

where $\alpha_{0c} = \frac{\alpha_{01} + \alpha_1\alpha_{02}}{S}$, $\alpha_c = \frac{\alpha_1}{S}$, $S = 1 + \alpha_p = 1 + \alpha_1\alpha_2$.

* Following Smith (*7*) we mean by the term 'reliability' the measure of fluctuations of given element parameters.

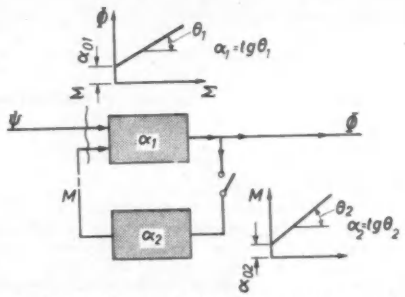


Fig. 2 Block diagram of single-loop feedback system

The value S is the so-called *stiffness* of the system. It shows us by how many times the gain and drift of the direct element decrease when feedback is switched in.

Let us consider an example. Suppose that there are no drifts: $\alpha_{10} = \alpha_{02} = 0$ (we have a.c. amplifiers only). The error is caused by the small changes of gain factors α_1 and α_2. Here the relative error of the system is equal to the relative change of gain

$$\delta_c = \frac{\Delta\Phi}{\Phi} = \frac{\Delta\Phi/\psi}{\Phi/\psi} = \frac{\Delta\alpha_c}{\alpha_c}, \qquad \text{where } \alpha_c = \frac{\alpha_1}{1+\alpha_1\alpha_2} = \frac{\alpha_1}{S}.$$

According ao the known methods of measuring-device-reliability investigation, we replace the difference by the differential $\Delta\alpha_c = d\alpha_c$. So we get the expression for relative error.

$$\delta_c = \frac{\Delta\Phi}{\Phi} \cong \frac{d\alpha_c}{\alpha_c} = \frac{1}{\alpha_c}\left(\frac{\partial\alpha_c}{\partial\alpha_1}d\alpha_1 + \frac{\partial\alpha_c}{\partial\alpha_2}d\alpha_2\right) = \frac{1}{S}\delta_1 + \frac{\alpha_p}{S}\delta_2,$$

where $S = 1+\alpha_p = 1+\alpha_1\alpha_2$, $\delta_1 = \Delta\alpha_1/\alpha_1$, $\delta_2 = \Delta\alpha_2/\alpha_2$.

The analysis of the derived expression shows us that to increase the direct element reliability we have to use a very reliable feedback element having $\delta_2 \simeq 0$. Only when $\delta_2 = 0$ do we get $\delta_c = \delta_1/S$.

This conclusion is confirmed by experience.

Investigation of single-loop system by absolute-error definition

Practically, when intending to use feedback, we are forced to increase the gain of the direct element α_1 to keep the output value (i.e. the scale of the device) constant. In Fig. 3 we can see:

1 The system characteristic when the loop is open ($S = 1$)

$$\Phi = \alpha_{01} + \alpha_1\alpha_{02} + \alpha_1\psi \qquad (1)$$

2 The system characteristic when the feedback is switched in ($S \gg 1$)

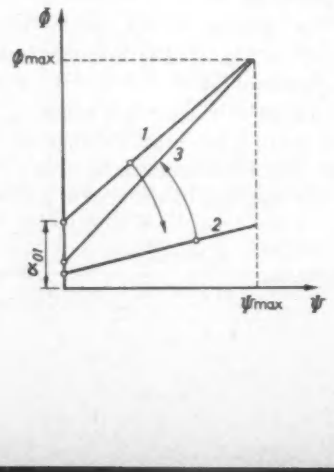


Fig. 3 Change of characteristic when feedback coefficient increases and output remains constant

$$\Phi = \frac{\alpha_{01}+\alpha_1\alpha_{02}}{S} + \frac{\alpha_1}{S}\psi \qquad (2)$$

3 The system characteristic with feedback, but after the gain α_1 is increased to the value α_1' to maintain the output

$$\Phi = \frac{\alpha_{10}+\alpha_1'\alpha_{02}}{S} + \frac{\alpha_1'}{S}\psi \qquad (3)$$

The new value of the gain coefficient of the direct element α_1' can be defined from the equation

$$\Phi_{max} = \Phi'_{max},$$

or

$$\frac{\alpha_{10}+\alpha_1'\alpha_{02}}{S} + \frac{\alpha_1'}{S}\psi_{max} = \alpha_{10}+\alpha_1\alpha_{02}+\alpha_1\psi_{max}.$$

From this equation we get

$$\alpha_1' = S\alpha_1 + \frac{(S-1)\alpha_{10}}{\alpha_{02}+\psi_{max}} \cong S\alpha_1 \qquad (4)$$

(because $S \gg 1$). So, the bigger the stiffness, the bigger the necessary change of gain. Let us consider an example. The gain coefficients are constant: $\alpha_1 = const.$, $\alpha_2 = const$. The error is caused by the drifts of zeros (we have d.c. amplifiers only). In this case, by differentiation, we get from equations 1, 3 and 4:

1 With no feedback ($\Delta\alpha_1 = 0$)

$$d\Phi \cong \Delta\Phi = \Delta\alpha_{10} + \alpha_1\Delta\alpha_{02}.$$

2 With feedback

$$\Delta\Phi = \frac{\Delta\alpha_{10}}{S} + \frac{\alpha_1'\Delta\alpha_{02}}{S} = \frac{\Delta\alpha_{10}}{S} + \alpha_1\Delta\alpha_{02}.$$

We come to the conclusion that feedback decreases the *absolute* error caused by zero drift of the direct element S times and almost does not change the error caused by zero drift of the feedback element. *The zero drift of the feedback amplifier can be compensated by the zero drift of the direct element.* The absolute error is equal to zero when the condition of invariance (compensation) is satisfied: $\Delta\Phi = 0$ when $\Delta\alpha_{02} = -\Delta\alpha_{01}/\alpha_1'$.

As proved in (5), absolute invariance by definite conditions does not depend on stability and stiffness S. Compensation may be reached by any value of them.

These conclusions are confirmed by experience.

It is easy to show that if we tried to investigate the problem of the first example by the method of absolute-error definition, or the problem of the second example by the method of relative-error definition, we would reach the wrong conclusions, i.e. conclusions not confirmed by experience. This means that really we have to choose the proper method for a given problem according to the rule stated above.

Investigation of two-loop system by relative-error definition

As we have said, using (at least!) the two-loop system we have a possibility of satisfying the condition of non-absolute invariance **2a**. Namely in this system we have the problem of finding the limit of the allowed increase of the inherent feedback gain.

The system under consideration is shown in Fig. 4. Let us suppose that the system is composed of a.c. amplifiers. The method of relative-error definition has then to be applied.

Linear equations of the elements are: control law $\Sigma=\psi-m_0\Phi-n_0M$; amplifier $M=\alpha_1\Sigma$; process $\Phi=\alpha_2M$. The static equation of the system is $\Phi=\Phi_0-\gamma L$,

where setting $\Phi_0=\dfrac{\alpha_1\alpha_2}{1+\dfrac{\alpha_1\alpha_2m_0}{1+\alpha_1n_0}}\psi=\dfrac{\alpha_1\alpha_2}{S}\psi$,

and coefficient of reset $\gamma=\dfrac{\beta}{1+\dfrac{\alpha_1\alpha_2m_0}{1+\alpha_1n_0}}=\dfrac{\beta}{S}$.

The gain of the closed system is:

$$\alpha_c=\frac{\alpha_1\alpha_2}{1+\dfrac{\alpha_1\alpha_2m_0}{1+\alpha_1n_0}}=\frac{\alpha_1\alpha_2}{S}.$$

By differentiation we find the expression for the relative error:

$$\delta_c=\frac{d\alpha_c}{\alpha_c}=\frac{1}{\alpha_c}\left(\frac{\partial\alpha_c}{\partial\alpha_1}d\alpha_1+\frac{\partial\alpha_c}{\partial\alpha_2}d\alpha_2+\frac{\partial\alpha_c}{\partial n_0}dn_0+\frac{\partial\alpha_c}{\partial m_0}dm_0\right)$$

$$=\frac{1}{S}\frac{1+2\alpha_1n_0+\alpha_1^2n_0+(\alpha_1\alpha_2)\alpha_1n_0m_0}{(1+\alpha_1n_0)^2}\delta_1+\frac{1}{S}\delta_2+\frac{1}{S}\frac{(\alpha_1\alpha_2)\alpha_1n_0m_0}{(1+\alpha_1n_0)^2}\delta_{n0}+$$

$$\frac{1}{S}\frac{\alpha_1\alpha_2m_0}{1+\alpha_1n_0}\cdot\delta_{m0}\cong\frac{1}{S}[1+(\alpha_1\alpha_2)\alpha_1n_0m_0+\ldots]\delta_1+$$

$$\frac{1}{S}\delta_2+\frac{1}{S}[(\alpha_1\alpha_2)\alpha_1n_0m_0+\ldots]\delta_{n0}+\frac{1}{S}(\alpha_1\alpha_2)m_0\delta_{m0}, \qquad (1)$$

where $\delta_1=\dfrac{\Delta\alpha_1}{\alpha_1}$, $\delta_2=\dfrac{\Delta\alpha_2}{\alpha_2}$, $\delta_{n0}=\dfrac{\Delta n_0}{n_0}$, $\delta_{m0}=\dfrac{\Delta m_0}{m_0}$

and stiffness $S=1+\dfrac{\alpha_1\alpha_2m_0}{1+\alpha_1n_0}$.

The analysis of the derived expressions shows that by increasing the gain $\alpha_1\alpha_2$ we have raised proportionally the demand on the reliability of elements α_1, n_0 and m_0. Only if $\delta_1=\delta_{n0}=\delta_{m0}=0$ we get $\delta_c=\delta_2/S$.

So we have reached our goal: we have used the apparatus of the theory of measuring-device reliability to clarify the principal question of invariance theory regarding the limit on use of the non-absolute-invariance condition **2a** (see table). In the case when the system under investigation consists of d.c. amplifiers we must use the method of absolute-error definition to solve the problem. We do not know yet how systems having a.c. and d.c. amplifiers simultaneously may be investigated.

Practical calculation of reliability necessary for inherent feedback elements

Expression 1 can be considered as the practical formula to calculate the static error δ_c if the rigid part of error $\delta_{n0}=\Delta n_0/n_0$ is known. But it is clear that this is not enough because inherent feedback has not only its rigid part n_0 but the elastic components n_1 and n_2 too.

$$n(p)=n_0+n_1p+n_2p^2+\ldots$$

To investigate the influence of small changes of n_1 and n_2 on reliability we can use the expressions for the dimensionless parameters: $x=f_1(n_1n_2)$, $y=f_2(n_1n_2)$. For example, for the two-loop system we can write such equations as: control law $\Sigma=-\varphi-n(p)M+l(p)\lambda$, where $\varphi=\Phi-\psi$; amplifier $\mu=Y_1(p)\Sigma$; process $\Phi=Y_2(p)\mu-\beta L$; where Φ is the controlled variable, μ the manipulated variable, L the load and ψ the reference. When

$$Y_1(p)=\frac{\alpha_1\alpha_2}{(\tau_1p+1)(\tau_2p+1)};\quad Y_2(p)=\frac{\alpha_c}{(\tau_2p+1)}$$

we get the system equation:

$$(a_3p^3+a_2p^2+a_1p+a_0)\varphi=-(b_2p^2+b_1p+b_0)\lambda,$$

where:
$a_3=\tau_1\tau_2\tau_3+\alpha_1\alpha_2n_2\tau_3$
$a_2=\tau_1\tau_2+\tau_1\tau_3+\alpha_1\alpha_2n_0\tau_2$
$a_1=\tau_1+\tau_2+\alpha_1\alpha_2n_1$
$a_0=1+\alpha_1\alpha_2\alpha_3$
$b_2=-\alpha_1\alpha_2\alpha_3l_2+\beta\tau_1\tau_2+\alpha_1\alpha_2\beta n_2$
$b_1=-\alpha_1\alpha_2\alpha_3l_1+\beta[\tau_1+\tau_2+\alpha_1\alpha_2n_1]$
$b_0=-\alpha_1\alpha_2\alpha_3l_0+\beta.$

Characteristic equation:

$$a_3p^3+a_2p^2+a_1p+a_0=0.$$

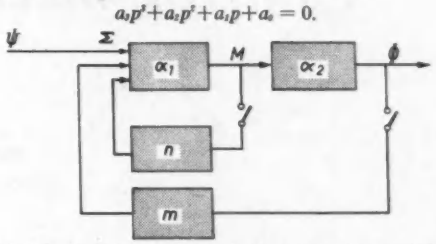


Fig. 4 Block diagram of two-loop system having inherent and external feedbacks

Using the new time scale

$$\omega_0=\left(\frac{a_0}{a_3}\right)^{\frac{1}{3}},\quad T=\omega_0t,\quad p=\frac{d}{dt},\quad D=\frac{d}{dT},\quad p=\omega_0D$$

we get $$D^3+xD^2+yD+1=0,$$

where $x=\dfrac{a_2}{\sqrt[3]{(a_0a_3^2)}}=f_1(n_1n_2)$; $y=\dfrac{a_1}{\sqrt[3]{(a_0^2a_3)}}=f_2(n_1n_2)$.

Using again the methods of measuring theory we find the additional calculation formulae. For example, in the case of relative error definition (i.e. a.c. amplification) we get:

$$\delta_x=\left(\frac{\partial f_1}{\partial n_1}\right)\frac{n_1}{x}\delta_{n1}+\left(\frac{\partial f_1}{\partial n_2}\right)\frac{n_2}{x}\delta_{n2} \qquad (2)$$

$$\delta_y=\left(\frac{\partial f_2}{\partial n_1}\right)\frac{n_1}{y}\delta_{n1}+\left(\frac{\partial}{\partial n_1}\right)\frac{n_2}{y}\delta_{n2} \qquad (3)$$

where $\delta_x=\dfrac{\Delta x}{x}$, $\delta_y=\dfrac{\Delta y}{y}$, $\delta_{n1}=\dfrac{\Delta n_1}{n_1}$, $\delta_{n2}=\dfrac{\Delta n_2}{n_2}$.

We derived the system of three equations having three unknown variables. Using the formulae 1, 2 and 3 we can calculate the necessary demands on the elements of inherent feedback δ_{n0}, δ_{n1} and δ_{n2} if we know the changes of the parameters x, y and α_c which are allowed (relative values δ_x, δ_y and δ_c).

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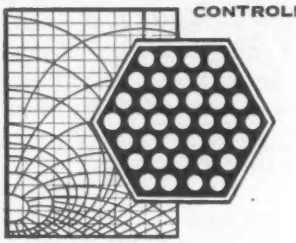

CONTROLLING NUCLEAR POWER—3

There are many tricky problems in the control of nuclear power reactors, but engineers can answer the physicists' demands

PART B

Control mechanisms for nuclear reactors

by **JOHN TINDALE, M.I.MECH.E.**
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In Part A last month we described the kind of nuclear power reactor that is used in this country. We then explained what controls are needed in such reactors, how the control information is obtained, and what the controls actually do. Finally we gave an account of control rod mechanisms.

POWER SUPPLY FOR CONTROL RODS

To raise and lower the control rods at the required low speeds necessitates very special arrangements.

If an ordinary squirrel-cage motor were used, uncoupling would be required in an emergency drop because a 50-c/s supply would need either a large gear-reduction or a high-inertia motor (multi-pole). In the latter case a possibility could occur of running at a higher speed than designed.

A better method is to use synchronous motors as described previously, with a generated low-frequency supply using basically d.c. generators.

Generation of low-frequency supply

Method 1 (*Fig. 9*) Three d.c. generators have fields fed from three potentiometers. The supply to these potentiometers is from a common source; battery, rectified a.c. mains, or exciter. Each pick-off at each potentiometer is displaced 120° respectively, and they are all driven by a common shaft from a gear-box. The gear-box has three speeds, one for withdrawal (low), and one low and one high for insertion. Choice of speed is made by the control engineer at the desk.

A constant-speed motor with an irreversible coupling drives the gear-box, and the speeds and direction of the output shaft are controlled by magnetic clutches operated remotely from the control desk. Sinusoidal currents produced by the potentiometers are fed to the three generator fields, phased at 120° to each other. The generator outputs therefore provide a three-phase supply

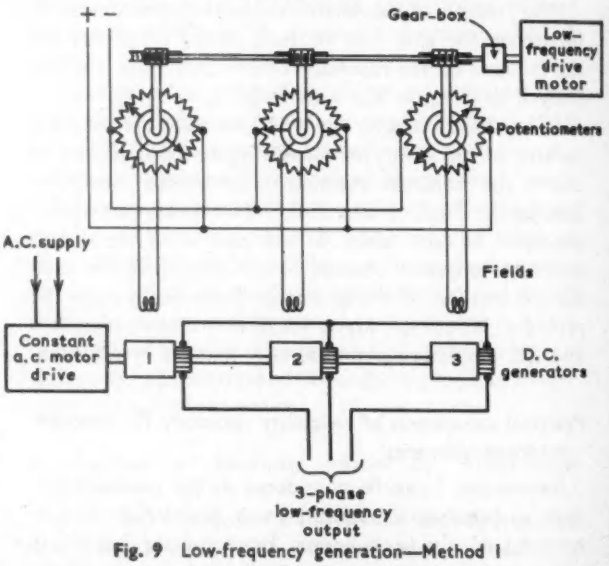


Fig. 9 Low-frequency generation—Method 1

of a frequency dependent upon the shaft-speed output from the gear-box driving the potentiometer brushes.

Method 2 (*Fig. 10*) This consists of a conventional d.c. generator with a field fed from a separate exciter. The commutator is special in that it is arranged to have not more than about 1V potential difference between

contiguous bars. Instead of two brushes as in a normal machine, it has three or multiples of three, according to the numbers of pairs of poles. The brushes are spaced at 120° (electrical) apart.

By mounting the brushes on a rotatable spider, alternating current of frequency proportional to their speed of rotation is provided; one half-cycle being completed by a brush moving from a *N* to a *S* field pole.

Method 3 The two described methods use rotary machines, and as such require continual inspection of brushes and bearings. A method which may be termed 'semi-static' is attractive, since it only involves rotation at those speeds related to the low frequency required. Brushes and bearings therefore function satisfactorily for long periods without attention. An a.c. machine has a rotor wound for a single-phase supply and each pole-shoe of the rotor covers an angle of 45°. Its stator is wound for three-phase supply but it has two sets of three-phase windings, each displaced 90° from the other.

In Fig. 11, phase A1 is displaced by 90° from phase A2, B1 from B2, C1 from C2 respectively. Consider first A1 and A2. As the rotor is turned, the e.m.f. induced in A1 will rise and fall sinusoidally for 90°, then remain at zero, while the e.m.f. induced in A2 rises and falls and so on (Fig. 12). By rectifying the output from A1 a positive d.c. voltage is obtained at a level represented by the sine of the angle of the rotor field cutting coils A1. By rectifying the output from A2 a similar but negative voltage is obtained, which, if plotted (see Fig. 13) will continue the sinusoidal output at the point at which it came to zero from coil A1. Thus if the output from each set of coils at 90° is fed to two separate windings in the same slots of a three-phase synchronous motor, then the motor will rotate synchronously with the rotation of the generator rotor. Continuous control of speed, and also direction is thus obtained without switching.

Emergency supply

Coarse control rods, when raised by the low-frequency supply, are brought to rest by reducing the low frequency to zero. The busbars are then phased with a d.c. supply of equal voltage from a battery and joined in parallel. The low-frequency generator is then disconnected, with the coarse-rod motors left 'hooked-up' on the battery supply.

SECONDARY SHUT-DOWN (FIG. 14)

A solenoid-controlled stop-valve contains the balls in the magazine. To release, the current is switched off and the stop-valve drops, thus dropping the balls. The armature is connected to the valve rod by a universal joint to allow it to sit squarely on the pole face.

FLUX-SCANNING MECHANISMS

Method 1 (*Fig. 15*) A tungsten alloy wire is lowered quickly (15 sec) into the reactor core, where it is irradiated for 30 min., then withdrawn quickly and wound

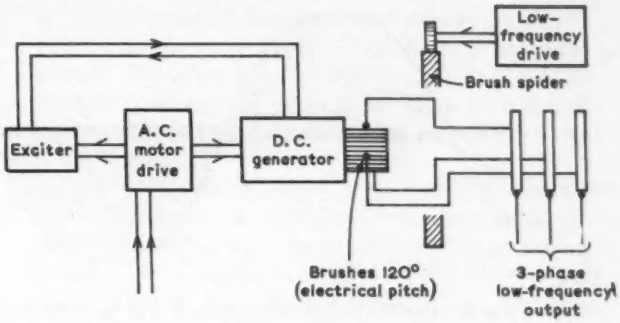


Fig. 10 Low-frequency generation—Method 2

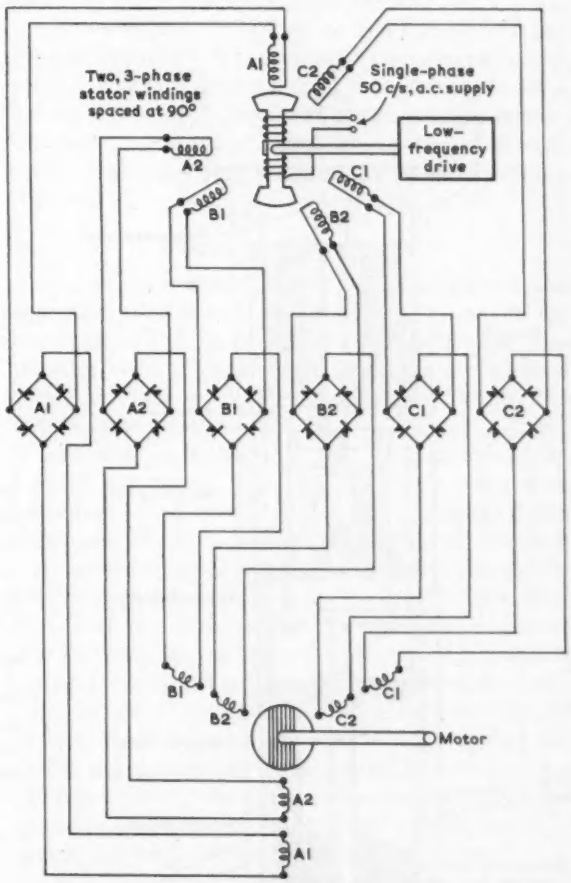


Fig. 11 Semi-static low-frequency generation—Method 3

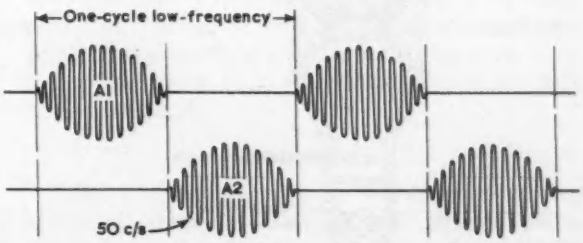


Fig. 12 A.C. output from coils A1 and A2

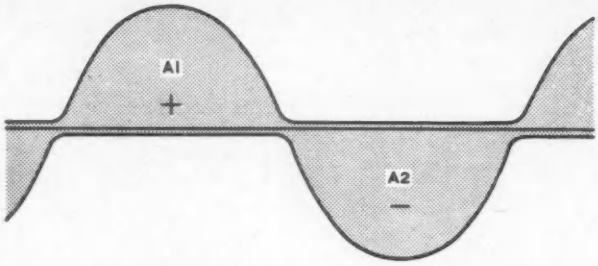
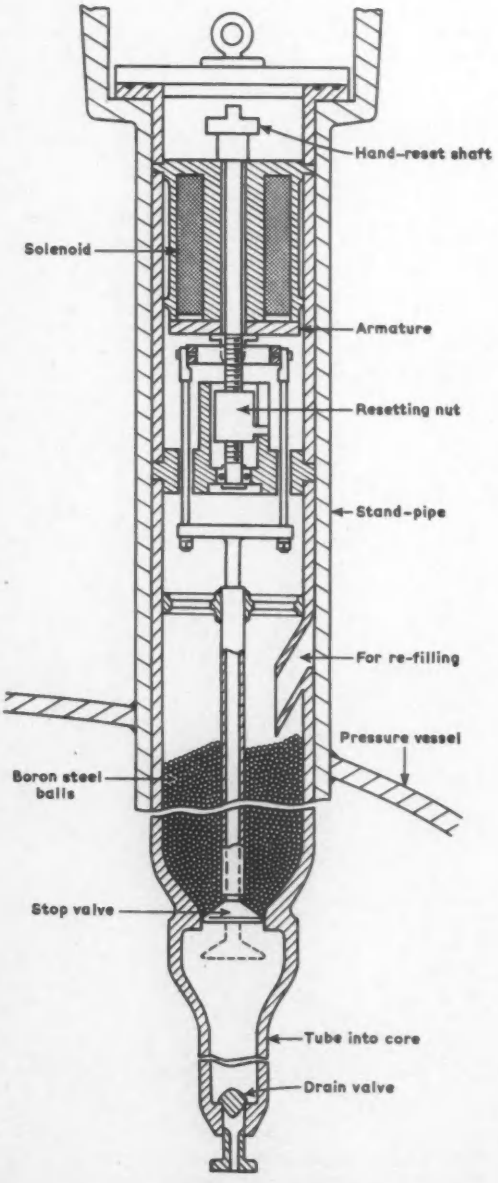


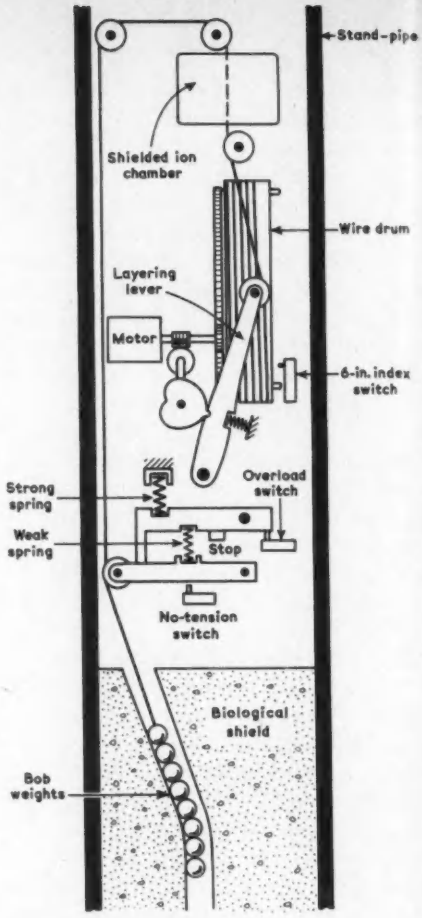
Fig. 13 (above) Rectified output from A1 and A2 to motor windings

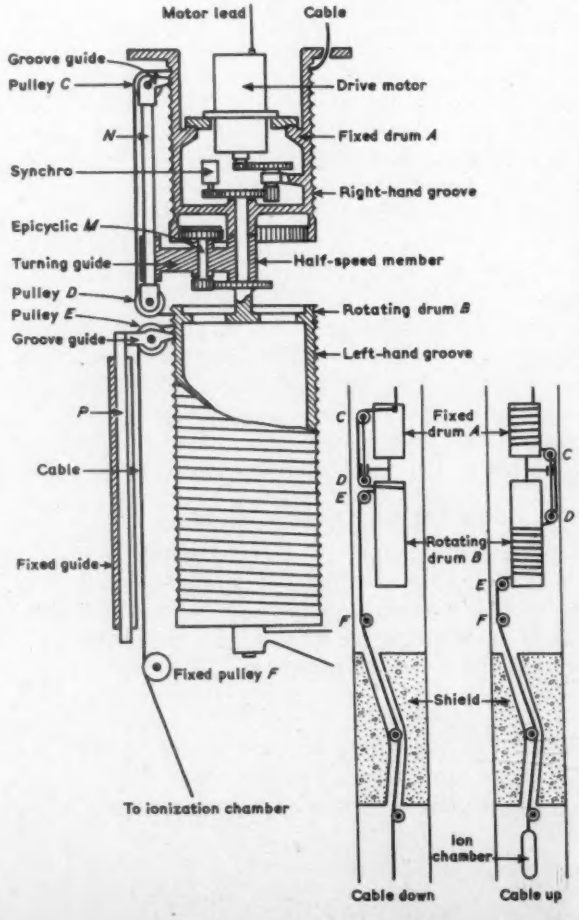
Fig. 14 (below) Emergency shut-down mechanism

Fig. 15 (right) Flux-scanning mechanism—Method 1

Fig. 16 (below right) Flux scanner—Method 2







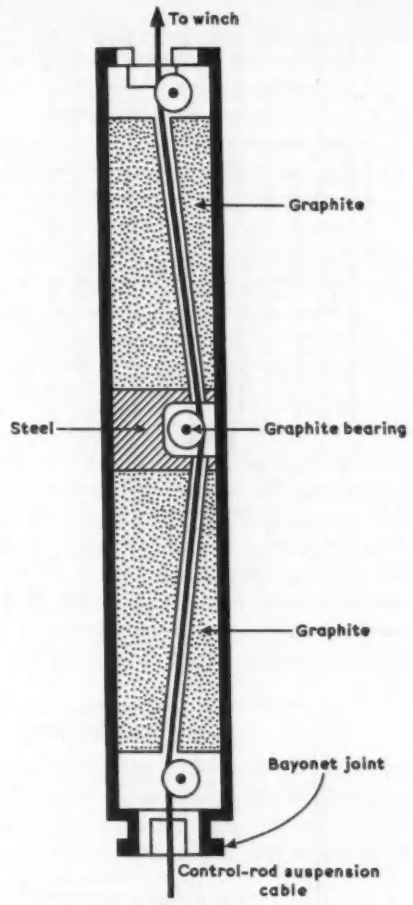


Fig. 17 Biological shield plug

on to a drum through an ionization chamber. No readings are taken whilst winding on to the drum. The wire is then unwound six inches at a time, and readings of radio-activity are recorded, with the wire stationary for about 3 min. in the ionization chamber. This process is continued until all the wire which was in the core has been measured. By this time the wire is suspended above the core in the stand-pipe. It is left there for several days, during which its activity becomes negligible and it may afterwards be used again.

By operating several of these flux scanners simultaneously an overall check is kept on neutron density. While the used tungsten wires are dissipating their activity, other groups are brought into use in sequence so that a continuous flux scan is recorded.

Three switches are fitted to the mechanisms. One to index the unwinding of the cable in 6-in. lengths, one to signal 'no-tension' in the case of the wire breaking or the bob weights fouling in the journey downwards, and one to signal an overload in the case of the bob weights fouling on the upward journey.

Method 2 (Fig. 16) An ionization chamber is suspended on a three-core electrical cable and slowly lowered into the reactor. The position of the chamber is indicated by a synchro transmitter geared from the cable winch mechanism. The level of the electrical signals from the ionization chamber prohibits the use of slip rings or any methods which may produce 'noise' in the circuit. The cable (for obvious reasons) must not be twisted whilst winding up or down. By using a special differential winch, slip rings are obviated and the cable is not twisted.

In Fig. 16, the top drum *A* is stationary and the cable is laid into its right-hand grooves by pulley *C*, rotated on its bearing *N* by epicyclic *M*. Whilst turning round *A*, *N* is engaged in a groove of the pulley so that pulley *C* coincides with the correct groove. Similarly pulley *D*, mounted also on *N*, takes off or lays the cable into the left-hand grooves of the bottom drum *B*. This drum rotates in the same direction as *N* but at twice its speed, by the action of epicyclic gear *M*.

Another pulley, *E*, takes off or lays cables on to the rotating drum *B*. The bearing *P* is engaged in the grooves of *B* so that, as it rotates, *E* is raised or lowered to keep pulley *E* coincident with the appropriate groove. The cable then is led on to pulley *F*, and so on through a biological-shield plug to connect on to the ionization chamber.

SPECIAL DESIGN FEATURES

Mechanisms operating control-rods, flux scanners and emergency shut-downs are placed at the top of the stand-pipes. They must be protected from high temperature and radiation. Each stand-pipe is furnished with a seal plug to contain the pressure, which may be as high as twenty atmospheres.

Suspended under the seal plug, for example in the case of the control rods, are the motor, resistances, cam-operated resistance switches, gear-box, winch drum, shield plug of graphite blocks or concrete in a stainless-steel tube, and lastly a sleeve valve. Each item is suspended from the next by a bayonet joint to give flexibility and ease of connexion. The sleeve valve diverts the hot gases into a hot-box manifold. This causes a stationary pocket of gas to accumulate above the sleeve valve, which is cooled by a blast of cold air directed between the biological shield and the stand-pipe. By this means the mechanism is maintained at a temperature of about 100°C, whereas the temperature of the hot gases may be of the order of 400°C. High-temperature greases are used for lubricating the gear-boxes.

Cables suspended in the reactor must be fed through the shield plug around pulleys which give them a fair lead through inclined slots (Fig. 17). This is to intercept the direct passage of γ-rays up to the top of the stand-pipe. The bearings of these pulleys are at a high temperature, and therefore graphite bushes are used.

The mechanisms for the flux-scanning apparatus have similar safeguards.

MAINTENANCE

When a mechanism has to be serviced it is removed completely from the stand-pipe and replaced immediately by another. In order to do this without shutting down it is necessary to design the system for remote

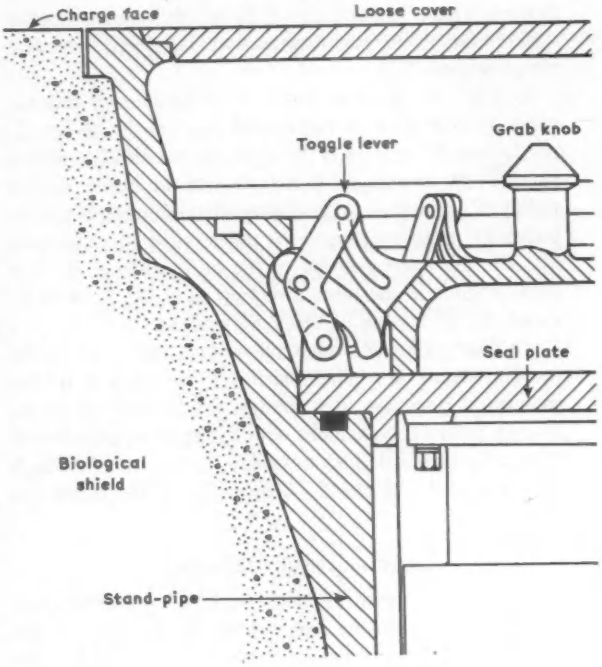
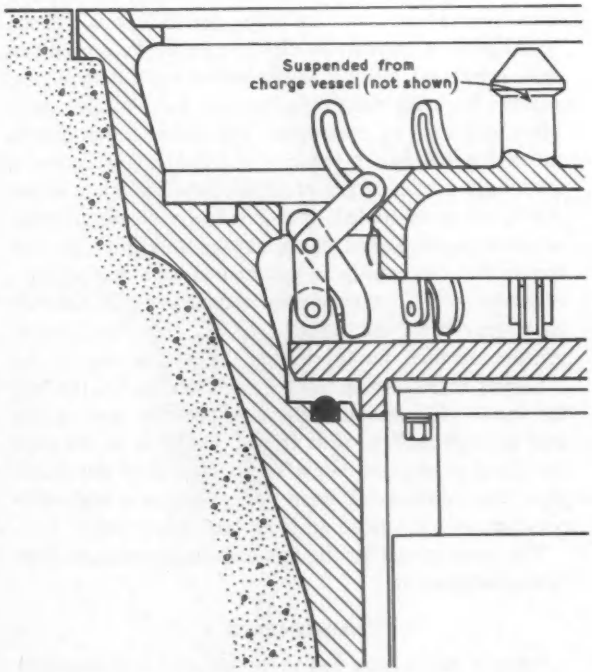


Fig. 18 Above, seal plug closed. Below, seal plug open



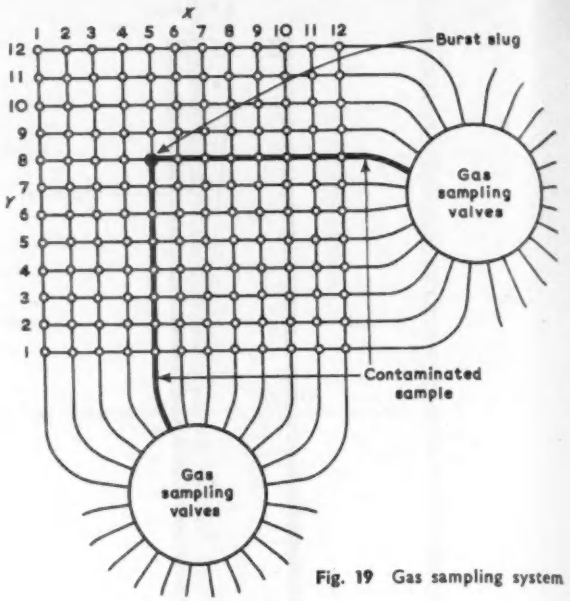


Fig. 19 Gas sampling system

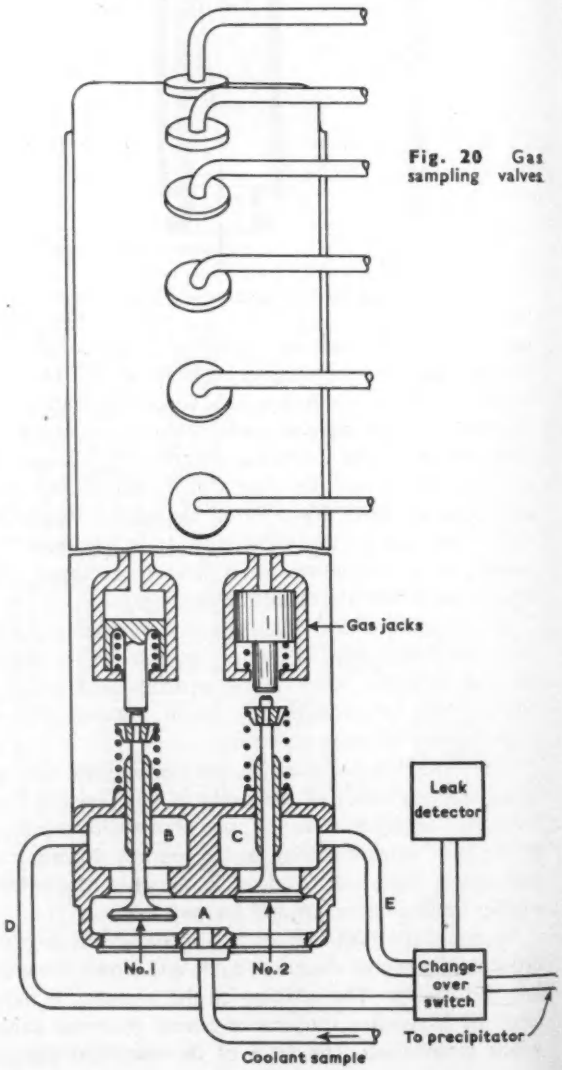


Fig. 20 Gas sampling valves

handling. With a control-rod mechanism, the gear must not be allowed to run out when the power supply is disconnected. The motor is therefore connected to the 'Manual' control which effectively locks the motor. The power plugs are then removed, and a charge machine is placed over the stand-pipe. The inside is purged of air, then filled with carbon dioxide gas at a pressure equal to that in the stand-pipe and pressure vessel. The seal plug is disconnected, lifted together with all the suspended apparatus and replaced by another complete set already in the charge-machine. The seal is made by remote control, the charge vessel is de-compressed, and removed. The power plug is connected and the lock released. The top seal of a stand-pipe must be capable of simple making and breaking by remote means. Fig. 18 shows a seal plug with toggle clamps which are broken by the crane grab inside the charge-machine, raising the retaining skirt which swings the toggles outwards (or inwards, according to the design), thus breaking the flange seal. In making the joint, the unit is lowered until the flanges come together, when the toggle clamps swing in the reverse manner, compress the flange joint and are secured by the skirt surrounding them.

GAS-SAMPLING VALVE

If one row of channels have their manifolds connected on the x axis, and again on a y axis, then by sampling systematically the x and y headers in turn it will be possible to trace a source of irradiation. For example, if

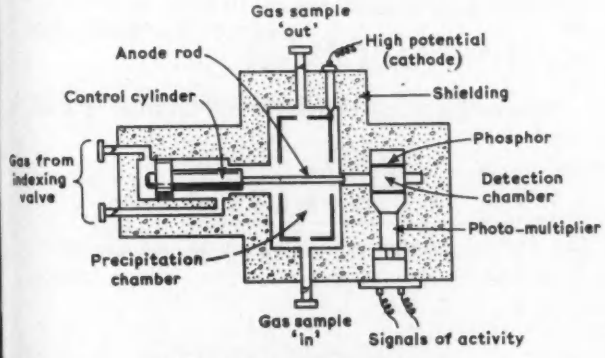


Fig. 21 Fission-product detector

$x5$ and $y8$ were active then the fault would lie at the intersection of these two manifolds. (Fig. 19). This reduces the time of monitoring considerably. For example, if there were a 12×12 arrangement then 144 separate sources of failure could ensue. By connecting and sampling twelve at a time, only 24 separate samplings in each cycle are necessary.

Coolant gas samples from the headers are joined to a gas sampling valve (Fig. 20). This valve is a part of a system which is cycled strictly to a time schedule. The gas sample enters a chamber *A*. This is unique to this particular header sample. The valve No. 1 lifts according to schedule, and the sample gas passes into chamber *B*. This chamber is common to the many valves in the systems similar to that shown, which are mounted around axis *XX*. The gas is ejected from *B* into pipe *D*, and flows to the detecting chamber (see below). After a sampling time of 30 sec. has elapsed, valve No. 1 is shut, and another valve, not shown but connecting another header to chamber *B*, is opened; and so on around the complete assembly of, say, some fifty valve systems, according to the number of headers.

If contamination is suspected the particular header is recorded and compared with a cross-reading thus obtaining the x and y ordinates of the particular fuel channel affected.

Valve No. 2 is in a duplicate system.

All the valves for all the headers are used in sequence on chamber *B*, during which time chamber *C* and pipe *E* is connected to a leak detector to check that all the valves are sound. When the complete cycle in chamber *B* is completed, chamber *C* is used for sampling and chamber *B* is connected to the leak detector, and so on. If a fault occurs, the gas samples are diverted by valves to a stand-by duplicate system.

FISSION-PRODUCT DETECTOR (FIG. 21)

The gas sample is blown into the chamber. If it is radio-active, particles will be precipitated on the wire rod. This is then thrust by a gas-propelled piston into a detecting chamber, which signals the presence of any radio-active deposit on the wire. Strict indexing is necessary to associate a fault condition with the origin of the sample gas. The induced activity on the wire dies away before sampling recommences.

CONCLUSION

In this short article I have endeavoured to give some idea of the problems involved in controlling a nuclear reactor.

Provided that the nuclear physicist defines the requirement, the engineer will be able to devise the means. None of the mechanisms described is revolutionary, all have been developed using well known engineering principles in an attempt to provide an elegant solution to those unique problems relating to the generation of power by gas-cooled nuclear reactors.

Acknowledgement

The author is indebted to the United Kingdom Atomic Energy Authority for permission to mention equipment developed by them. Also thanks are due to the Directors of Elliott Nucleonics Ltd. and Elliott Brothers (London) Ltd., for permission to describe mechanisms being manufactured by them.

NOTE: Many of the mechanisms described are the subject of patent application or patent pending by members of the Elliott-Automation group.

NEXT MONTH

The fourth article in the series will be 'Instrumentation of nuclear power stations' by Denis Taylor, M.Sc., Ph.D., M.I.E.E., F.Inst.P., of Plessey Nucleonics Ltd.

PART 2

The characteristic equations are formidable to look at, but their interpretations are quite simply stated

Boiler feed discharge systems under changing load

by **A. J. MORTON, M.SC., A.M.I.MECH.E.**
Central Electricity Generating Board

Last month, in the first part of this article, we expressed the opinion that the traditional design approach, without any stability or response calculations, is becoming inadequate for modern plant. We then made certain basic assumptions before considering the discharge system in detail.

CHARACTERISTIC EQUATIONS FOR COMBINED PUMP AND SYSTEM

General relationships

Conditions in the discharge system are related by the following equation, obtained by substituting equations 3 and 5 in 4:

$$K_P N + K_F y - (K_Q + K_S)Q - \frac{l\rho}{A}\mathrm{D}Q = 0 \qquad (13)$$

For the pump itself, equations 6 and 7 can be substituted in equation 8 to give

$$(K_D + K_T)N + \frac{\pi l}{30}\mathrm{D}N + K_R Q - K_G x - T_0 = 0 \quad (14)$$

System with constant-speed pump

Substituting equation 9 in 13,

$$\left[1 + \frac{l\rho}{A(K_Q + K_S)}\mathrm{D}\right] Q = \frac{K_F}{(K_Q + K_S)} y \qquad (15)$$

This equation relates the flow through the system to the lift of the regulating valve and is valid for small changes in either. The coefficient of DQ has the dimensions of time and is known as a simple exponential delay, since Q decays exponentially to its equilibrium value if this remains unchanged. This motion is completely stable and the flow will never oscillate of its own accord. If oscillations do occur they can be caused only by an oscillatory movement of the regulating valve (i.e. an oscillatory variation in y) or by some other effect not taken into account in formulating the basic equations.

System with speed-governed pump

Characteristic equation

Substituting equation 10 in 14,

$$N = \left[\frac{1}{K_D + K_T + K_G K_V + \dfrac{\pi l}{30}D}\right](T_0 - K_R Q) \quad (16)$$

Substitution of this expression into equation 13 leads to

$$\left[1 + \frac{\left(\dfrac{\pi l}{30}\cdot\dfrac{(K_Q + K_S)}{(K_D + K_T + K_G K_V)} + \dfrac{l\rho}{A}\right)}{\left(\dfrac{K_P K_R}{(K_D + K_T + K_G K_V)} + (K_Q + K_S)\right)}\mathrm{D} + \frac{\left(\dfrac{\pi l l\rho}{30A}\cdot\dfrac{1}{(K_D + K_T + K_G K_V)}\right)}{\left(\dfrac{K_P K_R}{(K_D + K_T + K_G K_V)} + (K_Q + K_S)\right)}\mathrm{D}^2\right] Q$$

$$= \frac{\left(\dfrac{K_P T_0}{K_D + K_T + K_G K_V}\right)}{\left(\dfrac{K_P K_R}{(K_D + K_T + K_G K_V)} + (K_Q + K_S)\right)} + K_F \left[\frac{1 + \dfrac{\pi l}{30}\cdot\dfrac{1}{(K_D + K_T + K_G K_V)}\mathrm{D}}{\left(\dfrac{K_P K_R}{(K_D + K_T + K_G K_V)} + (K_Q + K_S)\right)}\right] y \quad (17)$$

INTERPRETATION

System with speed-governed pump

The coefficients of D and D^2 will be positive for a pump of normal design, and it can be shown* that when this is the case the system is entirely stable, i.e. after any disturbance the flow will always tend to settle at its equilibrium value, either exponentially or with damped oscillations. It is important to realize that this statement refers only to the feed pump and its discharge system, and not to the whole feed-water control loop, which also includes the boiler, regulator and pneumatic system (if fitted). The significance of this has already been mentioned.

If the total moment of inertia I of the pump and turbine rotors is sufficiently small, the terms in D^2Q and Dy become negligible, and the equation is then of the same general form as equation 15, which relates to a constant-speed machine.

System with pressure-governed pump

Equation 20 is very similar in form to equation 17 relating to the speed-governed pump, except for the important difference that the denominators in the coefficients of DQ and D^2Q now contain a negative term which, if large enough, may render the main denominators themselves negative. It can be shown (see previous footnote) that equation 20 will then represent an unstable system. It appears however that with a pump and system of normal design the possibility of instability from this cause is very remote.

System with venturi-governed pump

Comparing equations 23 and 20, it is clear that the addition of the venturi element has introduced a second negative term into the denominators of the coefficients of D and D^2. This must inevitably mean a slower response of an otherwise identical pump and system to changed conditions, and in an extreme case could mean complete loss of stability. It will be seen later that this is a real possibility in practice.

* See for example R. H. Macmillan's 'Introduction to the Theory of Control in Mechanical Engineering' (Cambridge), p. 73.

System with pressure-governed pump

Characteristic equation

The governor valve lift x is now a function of discharge pressure, and hence of speed and flow, and can be expressed in terms of the last two quantities by substituting 5 into 11. This gives

$$x = -K_P K_W N + K_Q K_W Q \qquad (18)$$

which on substitution into equation 14 gives

$$N = \left[\frac{T_O + (K_G K_Q K_W - K_R)Q}{K_D + K_T + K_G K_P K_W + \frac{\pi I}{30}D}\right] \qquad (19)$$

This expression for N can be inserted into 13 and yields

$$\left[1 + \left(\frac{\frac{\pi I}{30}\cdot\frac{(K_Q + K_S)}{(K_D + K_T + K_G K_P K_W)} + \frac{l\rho}{A}}{\frac{K_P(K_R - K_G K_Q K_W)}{(K_D + K_T + K_G K_P K_W)} + (K_Q + K_S)}\right)D + \left(\frac{\frac{\pi I l\rho}{30A}\cdot\frac{1}{(K_D + K_T + K_G K_P K_W)}}{\frac{K_P(K_R - K_G K_Q K_W)}{(K_D + K_T + K_G K_P K_W)} + (K_Q + K_S)}\right)D^2\right]Q$$

$$= \left(\frac{\frac{K_P T_O}{(K_D + K_T + K_G K_P K_W)}}{\frac{K_P(K_R - K_G K_Q K_W)}{(K_D + K_T + K_G K_P K_W)} + (K_Q + K_S)}\right) +$$

$$K_F\left[\frac{1 + \frac{\pi I}{30}\cdot\frac{1}{(K_D + K_T + K_G K_P K_W)}D}{\frac{K_P(K_R - K_G K_Q K_W)}{(K_D + K_T + K_G K_P K_W)} + (K_Q + K_S)}\right] y \qquad (20)$$

System with venturi-governed pump

Characteristic equation

This is identical with the simple pressure-governed system except that the governor valve lift depends partly on flow as well as on discharge pressure and pump speed. The substitution of equation 5 into 12 gives

$$x = -K_P K_W N + (K_Q K_W + K_Y)Q \qquad (21)$$

which is the same as equation 18 apart from the addition of a venturi term on the right-hand side. Substituting 21 into 14,

$$N = \left[\frac{T_O + (K_G K_Q K_W + K_G K_Y - K_R)Q}{K_D + K_T + K_G K_P K_W + \frac{\pi I}{30}D}\right] \qquad (22)$$

and this on insertion into equation 13 gives

$$\left[1 + \left(\frac{\frac{\pi I}{30}\cdot\frac{(K_Q + K_S)}{(K_D + K_T + K_G K_P K_W)} + \frac{l\rho}{A}}{\frac{K_P(K_R - K_G K_Y - K_G K_Q K_W)}{(K_D + K_T + K_G K_P K_W)} + (K_Q + K_S)}\right)D + \left(\frac{\frac{\pi I l\rho}{30A}\cdot\frac{1}{(K_D + K_T + K_G K_P K_W)}}{\frac{K_P(K_R - K_G K_Y - K_G K_Q K_W)}{(K_D + K_T + K_G K_P K_W)} + (K_Q + K_S)}\right)D^2\right]Q$$

$$= \left(\frac{\dfrac{K_P T_0}{(K_D + K_T + K_G K_P K_W)}}{\dfrac{K_P(K_R - K_G K_Y - K_G K_Q K_W)}{(K_D + K_T + K_G K_P K_W)} + (K_Q + K_S)} \right) +$$

$$K_F \left[\frac{1 + \dfrac{\pi I}{30} \cdot \dfrac{1}{(K_D + K_T + K_G K_P K_W)} \mathrm{D}}{\dfrac{K_P(K_R - K_G K_Y - K_G K_Q K_W)}{(K_D + K_T + K_G K_P K_W)} + (K_Q + K_S)} \right] y \quad (23)$$

RESPONSE OF FLOW RATE TO FEED REGULATOR MOVEMENTS

Basic conceptions

With the aid of equations 15, 17, 20 and 23, the variation in flow rate produced by any reasonably simple movement of the feed regulator may be calculated. If the lift y of the feed regulating valve is known as a function of time, this function can be substituted into any of the above equations and a solution found for the flow rate Q in terms of time. For simplicity, only two types of regulating valve movement are considered, namely the unit step-function displacement, which consists of a sudden unit alteration in the value of y which thereafter remains constant, and the sinusoidal displacement of unit amplitude and of any frequency from zero to infinity.

The step-function conception is useful because it can often be approximately simulated in practice fairly easily, and may therefore afford a ready means of checking the theory, and also because it shows up the natural response of the system when allowed to settle without interference following a single sudden permanent shift of the equilibrium point. The sinusoidal displacement can also often be reproduced in practice with suitable equipment, and is important because it reveals, in a form very suitable for further calculation, the phase lag and amplitude of the response of the flow rate to oscillatory movements of the regulating valve.

The calculation of the step-function responses is best carried out by the Laplace transform method, while the sinusoidal response is most easily obtained by evaluating, as functions of $j\omega$, the transfer functions for Q in terms of y which are obtained from the appropriate system equations. Both these methods are well known and are given in outline below.

Response to step-function movements

General form of equation

The system equations 15, 17, 20 and 23 are all of the general form

$$\mathrm{F(D)}Q = C + \mathrm{f(D)}y \quad (24)$$

The constant C arises merely from the arbitrary datum adopted for Q (see Fig. 1). The transfer function for the variable part of Q in terms of y is therefore f(D)/F(D), and on applying this differential operator to the valve displacement y expressed as a function of time an expression emerges which gives the resulting variation in Q.

To express y as a direct function of time is not easy with a discontinuous movement such as a step function, and it is much simpler to rewrite the transfer function in terms of the complex variable s and to multiply it by the Laplace transform of the displacement, which is also a function of s. The resulting product is the Laplace transform of the flow rate, and can be converted, again using a standard table, into an algebraic expression for Q which does not contain any derivatives.

System with constant-speed pump

Equation 15 is of the form

$$[1 + T_1\mathrm{D}]Q = C_1 y \quad (25)$$

the transfer function for Q in terms of y being

$$\frac{C_1}{1 + T_1\mathrm{D}} \quad (26)$$

or, in terms of the complex variable s,

$$\frac{C_1}{1 + T_1 s}$$

The Laplace transform for a unit step-function displacement (i.e. a sudden unit increase in valve lift y),

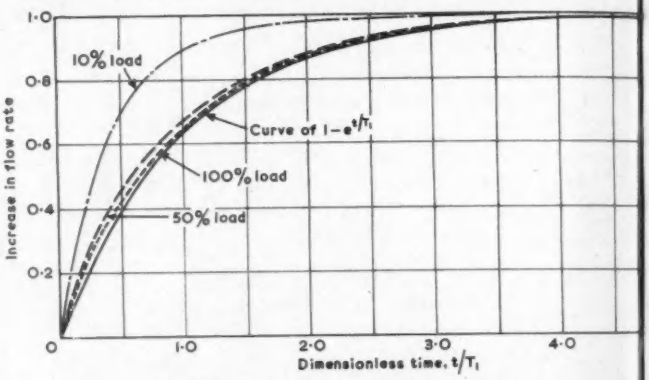


Fig. 3 Response curves for step-function disturbances

assuming all variables initially zero and stationary, is $1/s$ which on multiplication by the above transfer function becomes

$$\frac{C_1}{s(1 + T_1 s)} = C_1 \left\{ \frac{1}{s} - \frac{1}{\left(\dfrac{1}{T_1} + s\right)} \right\} \quad (27)$$

This is the Laplace transform of Q, and the inverse transform is

$$Q = C_1(1 - e^{-t/T_1}) \quad (28)$$

The expression in the bracket is plotted in Fig. 3, which shows the exponential law followed by the flow rate in changing from its initial equilibrium value of zero to an ultimate equilibrium value of unity. The constant C_1 has here been dropped for convenience, and this curve therefore corresponds to a sudden increase of $1/C_1$ in the value of y. The departure of Q from its final equilibrium value is reduced in the ratio $1/e$ in each successive time interval T_1, which is the exponential delay of the system. T_1 is also the time which would be taken to reach final equilibrium if the initial rate of approach were maintained.

To be continued

Methods of measuring radio-activity are well established, but an outstanding problem is how to make large numbers of measurements automatically and economically

Improvements in radio-activity monitoring

by **DENIS TAYLOR, M.SC., PH.D., M.I.E.E.**
Plessey Nucleonics Ltd and Hagan Controls Ltd

The increasing use of radio-active materials in industry has brought with it an increasing need for radio-activity monitoring. All existing instruments for measuring low radio-activities are basically integrating devices, which count the occurrence of events in a radiation detector. Such methods are necessarily time-consuming, particularly if the activity of the sample is very weak.

As the use of monitoring extends, attention is being given to the problem of finding more economical testing methods. This problem is largely statistical. Dr Taylor here states some basic considerations, and goes on to describe the recently introduced 'parallel boundary' sequential testing technique. The efficiency of this technique is compared with that of the established 'rectangular boundary' method.

MANY LABORATORIES AND FACTORIES CONCERNED WITH using radio-active materials are today involved in a great many routine radio-active assays. The number of samples to be assayed each day varies, of course, according to the nature of the program, but much of it can be exceedingly laborious as it may involve counting the radio-active emissions over long periods of time (up to several hours in some cases) to obtain the required statistical accuracy of measurement. This is a process which can be made automatic, and it is normal practice to install automatic radio-active assay apparatus for these routine measurements.

Types of control

One of the special problems which arises with this type of apparatus is the form to be taken by the controller. If time-controlled operation is employed, each sample will be counted for a certain preset time. This is convenient if all samples are approximately of the same activity, because then all measurements will be made to approximately the same statistical accuracy. On the other hand if the samples are of widely varying activities the precision of measurement will vary widely from sample to sample. A more satisfactory method might be to use count-controlled operation instead of time-controlled operation. All measurements would then be made to the same statistical accuracy, but very weak samples might be assayed for an unduly long time. A more satisfactory method is to arrange an overriding time control so that in the case of very weak activities for which a fixed number of counts would occupy too long a period, the count is terminated by the overriding time control.

Still another method, which has found favour in some quarters, is to terminate the counting period by a summation number determined by the sum of the counting pulses from the radiation detector and the timing impulses from a standard clock mechanism. If n is the total number of counts plus time impulses and t is the total number of time impulses (say 1-s time impulses) during a measurement, then the counting rate is $(n-t)/t = n/t-1$. When the counting rate is high, the number n comprises a large number of count pulses from the radiation detector and a small number of time impulses. This means that frequent recordings of the counting rate are made. When the counting rate is low,

n comprises mainly time impulses, and recordings are made infrequently. By a suitable choice of the number n and the frequency of the timing impulses it is possible to achieve a reasonable statistical accuracy for the higher counting rates (or more active samples) without wasting time unnecessarily on the lower counting rates (or weak activities).

Another proposal for improving the efficiency of cer-

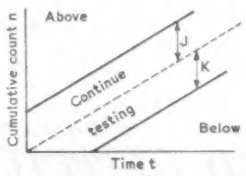


Fig. 1 Principle of sequential test

tain routine radio-activity monitoring by introducing a rapid sorting process was made last year by Barnes (*1*), and the equipment required was described by Moss at the recent Medical Electronics Conference (1960) organized by the Institution of Electrical Engineers.

In counting operations of this type, which involve counting many weak radio-active samples, it is often only the most active samples which are of quantitative interest. Barnes therefore suggests that all samples be subjected to a rapid preliminary sorting operation which rejects the samples of low activity, and that this should be followed by accurate measurement of the few remaining samples. It is possible to achieve high efficiency of a sorting process based on a sequential test, and this will, in general, more than compensate for the fact that the stronger samples pass through two counting operations.

SEQUENTIAL TESTING

In many fields of health physics and medicine it is found that the distribution of samples is such that only about one sample in a hundred is significantly active and

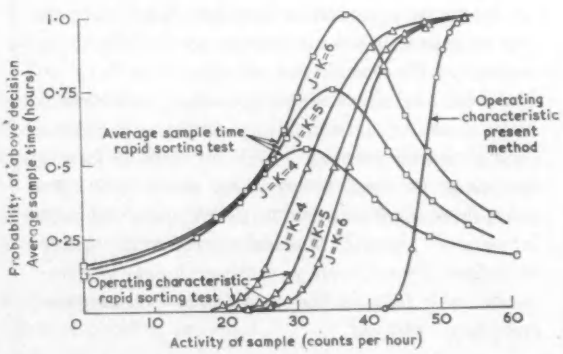


Fig. 2 Performance of rapid sorting tests. (Investigation level 48 count/min.)

therefore requires the longer and second counting operation. In the system described by Barnes for the examination of filter paper samples, the preliminary sorting operation uses a sample time of ten minutes, and then the 'high' samples are counted again for eight hours. It will be noted that on the basis of the 1:100 ratio mentioned earlier this reduces the average time per sample from eight hours to about twenty minutes.

The preliminary sorting process uses a sequential test, in which the counting period does not have a fixed duration, but terminates as soon as the test gives a result with an acceptably low probability of error. The test depends upon the determination of the difference between the observed number of counts (n) and the number ($\lambda_s t$) expected at a counting rate λ_s, where λ_s is related to the investigational level. The test is allowed to continue while ($n-\lambda_s t$) lies between two limits J and K, but if ($n-\lambda_s t$) reaches the upper limit J or the lower limit K the test terminates with the 'above investigation level' or 'below investigation level' decision, respectively. By a suitable choice of J, K and λ_s it can be arranged that the risk of a wrong 'below' decision is no greater than the similar risk in the earlier methods described. The method is summarized in Fig. 1. Fig. 2 shows the performance obtained.

Each counting channel in the automatic apparatus requires a means of forming the quantity ($n-\lambda_s t$) and comparing it with the preset boundary values J and K. Where digital methods as proposed by Barnes are used, each counting channel has a both-way counting device (register) which adds one unit when a pulse is received from the radiation detector and subtracts one unit at regular intervals of time $1/\lambda_s$. When the total stored in the register reaches J (positive) or K (negative) the test is complete. In the apparatus described by Moss, Dekatron tubes are employed for the counting operations.

The 'parallel boundary' method

Interest in sequential counting methods was aroused again recently by the reading of a paper entitled 'Rapid Methods for Ascertaining whether the Activity of a Weak Radioactive Sample exceeds a Pre-determined Level' by E. H. Cooke-Yarborough and R. C. M. Barnes on 25 October, 1960 at the Institution of Electrical Engineers. This new paper dealt with the application of sequential count procedures in the routine measurement of radio-activity on the hands. In the past, two circuits have been used in hand monitors, a counting circuit and a timing circuit. The counting circuit is fed with charge pulses from the radiation detectors, and these are employed to charge a capacitor which, when it rises to a set voltage, operates a trigger circuit operating the 'high' alarm. Meantime constant current is fed to a capacitor in the second (timing) circuit which operates a 'low' alarm if it reaches the preset voltage first. At the end of this period both capacitors are discharged and the sequence started again.

In the new circuit proposed by Cooke-Yarborough and Barnes, charge is fed to a capacitor from the discharges of the detectors as in the previous system, but a constant current (corresponding to that current which would be fed to the capacitor with a maximum permissible level of contamination on the hands) is bled

from the same capacitor. It is therefore a differential method. Consider now the hands having been tested with no contamination; the voltage on the capacitor will fall eventually to the preset negative voltage, causing the 'low' indicator to operate. Similarly, heavily contaminated hands would cause the 'high' indicator to operate. Hands contaminated at intermediate levels would cause the voltage to fluctuate with the usual statistical variations, eventually operating either the 'high' or 'low' level indicators.

This 'parallel boundary' method, as the authors call it, provides a considerable saving in time as compared with the usual method, and according to computations which have been carried out at A.E.R.E., reduces the time taken by a factor of between five and seven.

The parallel boundary method not only provides a means of saving time without losing accuracy; it can also provide increased accuracy without an increase of average sampling time.

Comparison of method efficiencies

At the Institution meeting, Cooke-Yarborough and Barnes gave a detailed comparison of the parallel-boundary test, which they advocate, and the rectangular-boundary test, which terminates when either the count of observed events or the duration of the test exceeds pre-determined limits. The table summarizes some of the results which were described.

Comparison between average times taken by rectangular-boundary and parallel-boundary tests

CONDITIONS OF TEST	AVERAGE TIME (s)	
	RECTANGULAR-BOUNDARY TEST.	EQUIVALENT PARALLEL-BOUNDARY TEST
(a) Tolerance rate 5 counts/s (no background activity). Activity uniformly distributed between zero and 10 counts/s.	5·90	3·35
(b) As (a), but 90% of samples inactive. Remainder uniformly distributed between zero and 10 counts/s.	6·90	1·41
(c) Tolerance rate 5 counts/s superimposed on 20 counts/s background. Activity uniformly distributed between background and background plus 10 counts/s.	33·4	16·7
(d) As (c), but 90% of samples inactive (background only). Remainder uniformly distributed between background and background plus 10 counts/s.	34·8	7·08
(e) As (b), but discriminating power increased five-fold.	172	8·04

It will be seen that the rectangular-boundary test, which has been widely used in hand monitors in the past, is much less efficient than the parallel-boundary test. For a typical distribution of radio-activity, with a predominance of uncontaminated personnel, the average duration of the parallel-boundary test is approximately one-fifth of that for the commonly used rectangular-boundary test having similar discriminating power.

Although the parallel-boundary procedure greatly reduces the average duration of the test, it suffers from the disadvantage that some samples, with activity near the maximum permissible level, may require an excessively long test before a decision is made. This effect can be overcome by imposing a limit to the duration of the test.

OTHER APPLICATIONS

At the Institution Meeting at which the above paper was presented, several other applications of this technique were discussed. One fairly straightforward application was that of body monitoring, where the problem is to decide whether persons involved in a radio-activity accident have inhaled or absorbed radio-active materials. This is therefore another problem of sorting the contaminated persons from the persons who are not contaminated, or only slightly contaminated.

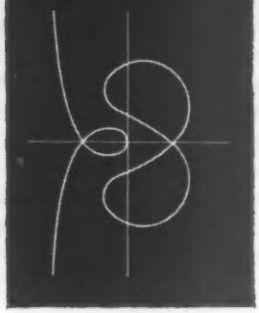
Another problem discussed was that of burst slug detection (b.s.d.) equipment for nuclear power stations. It was noted that adapting the technique to the scanning type of b.s.d. system would be difficult, as this would involve the design of a mechanical scanning valve to select the gas samples from each fuel-element channel in turn, remaining on each channel for a variable time according to the activity found. It seems that the trends to continuous monitoring systems instead of scanning systems described by Hough (2) will be maintained, as reductions in the cycle time made possible using the methods of Cooke-Yarborough and Barnes can only be obtained at the expense of considerable complication in other directions.

Plant control

An obvious question is whether this new technique can be applied to plant control problems. Here the problem is not whether the activity is above a certain predetermined level, but whether it is between certain preset limits, and we want to know whether the measured parameter moves outside these limits. At first sight it would seem that sequential counting is not of value here, because we are interested in monitoring the sample between the two predetermined limits which call for the long counting time. However, if we adopt the point of view that our controls maintain the activity between the required limits, and consider the new technique for providing a particularly quick-acting system of indicating when the activity changes above or below the preset bank of activity levels over which control is provided, it begins to look possible. The meeting appeared to be of the opinion that these methods could be exploited in process plant problems.

References

1. A.E.R.E. Report R.3112, October 1959.
2. Hough, G. V.: paper presented to the Instruments and Measurements Conference, Stockholm, September 1960.



NUMBER TWO OF A SERIES

How the pattern of poles and zeros is connected with the frequency response of a system, and where the poles must lie if the system is to be stable

Pole-zero approach to system analysis

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In Part 1 complex frequencies of the form $e^{pt}=e^{(\alpha+j\omega)t}$ which can represent a wide variety of disturbances, both oscillatory and non-oscillatory, were considered together with an associated p-plane in which a point corresponded with a particular form of oscillation. The solutions of a second-order differential equation were investigated and plotted in the plane, and variation of the damping parameter caused motion of the solution points in the plane.

Transfer function

The equation relating input and response for a general second-order system is

$$a_2\frac{d^2y}{dt^2}+a_1\frac{dy}{dt}+a_0y=x$$

where x, y, are respectively input and response, and a_0, a_1, a_2, are coefficients depending on the particular system. If complex frequency forms are assumed for input and response

$$x=Xe^{pt};\ y=Ye^{pt}$$

these may be substituted to give

$$Y(p)/X(p)=1/(a_2p^2+a_1p+a_0)$$

This process may be applied to differential equations of any order to yield an input-response relation or *transfer function* with denominator polynomial obtained from the original equation. For example the equation

$$b_1\frac{dy}{dt}+b_0y=x$$

yields

$$Y(p)/X(p)=1/(b_1p+b_0)$$

while the equation

$$c_3\frac{d^3y}{dt^3}+c_2\frac{d^2y}{dt^2}+c_1\frac{dy}{dt}+c_0y=x$$

yields

$$Y(p)/X(p)=1/(c_3p^3+c_2p^2+c_1p+c_0)$$

For such transfer functions, since the denominator is derived from the original differential equation of the system, the particular values of p, say p_k, which cause the denominator to equal zero, correspond with the natural modes of oscillation e^{p_kt} for the system.

In more general cases a transfer function is obtained which is a *ratio* of polynomials instead of only a denominator function of p. The simple network of Fig. 1 yields the transfer

$$\frac{E_i}{E_o}(p)=\frac{pC_1R_1R_2+R_2}{pC_1R_1R_2+R_1+R_2}$$

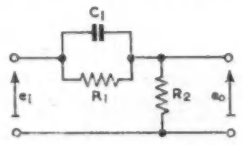

Fig. 1 Electrical network yielding a transfer function which is a simple ratio of polynomials in p

A spring-mass-dashpot system as in Fig. 2, where both spring rates and masses are the same, will yield a transfer between applied force f, and displacement y, of the same mass

$$\frac{Y}{F}(p)=\frac{Mp^2+Dp+K}{M^2p^4+MDp^3+3MKp^2+2KDp+K^2}$$

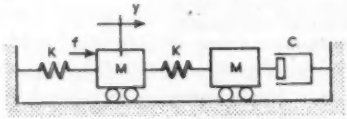

Fig 2 Mechanical system yielding polynomial ratio for the transfer (Y/F)(p)

but natural modes are still given by the values p_k which cause the denominator to vanish.

Interpretation of factors in the p-plane

The general form that the transfer function for a system takes is a ratio of polynomials

$$T(p) = \frac{a_m p^m + a_{(m-1)} p^{(m-1)} + \ldots a_1 p + a_0}{b_n p^n + b_{(n-1)} p^{(n-1)} + \ldots b_1 p + b_0} = \frac{N(p)}{D(p)}$$

and if the coefficients have numerical values the ratio can be factorized into the form

$$T(p) = \frac{a_m (p - p_a)(p - p_b) \ldots\ldots}{b_n (p - p_1)(p - p_2) \ldots\ldots}$$

where the specific values p_a, p_b, ..., p_1, p_2, ..., are the *roots* of $N(p)$, $D(p)$, since when

$$p = +p_a, +p_b, \ldots\ldots \text{ or } +p_1, +p_2, \ldots\ldots$$

either $N(p)$ or $D(p)$ becomes zero.

In actual practice the factorization process may be a considerable problem, but for the present purposes, which are essentially concerned with ideas and principles, it is not quite so important.

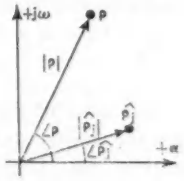

Fig. 3 Values for p for interpretation of $(p - p_j)$ in p-plane

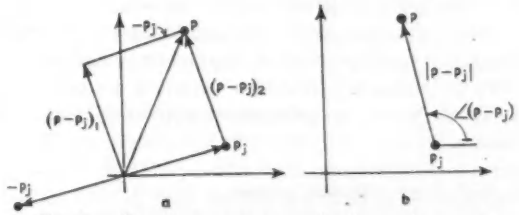

Fig. 4 a Graphical construction for factor $(p - p_j)$
b Direct interpretation of factor $(p - p_j)$

A general factor $(p - p_j)$ of either $N(p)$ or $D(p)$ concerns two values of the complex variable, a specific value p_j, and an arbitrary value p which may be anywhere in the plane. Each value may be represented in the complex plane by a line* from the origin to the particular point as in Fig. 3, and the statement

$$(p - p_j) \text{ or } (p + (-p_j))$$

may be represented graphically as in Fig. 4a, where the value

$$(p - p_j)_1$$

is obtained by adding $-p_j$ to p. However it can also be seen that

$$(p - p_j)_1 = (p - p_j)_2$$

and hence the value of the factor $(p - p_j)$ for *any* value of p is represented by the line joining p_j to p, and the actual numerical value of the factor may be obtained by direct measurement on a scaled diagram as in Fig. 4b. This graphical interpretation of factors in the p-plane is a very important concept in complex frequency analysis and root locus methods.

* The terms *vector*, *sinor*, *phasor* are used for the line.

A polynomial, for example a cubic,

$$F(p) = p^3 + a_2 p^2 + a_1 p + a_0$$

could be factorized as

$$F(p) = (p - p_a)(p - p_b)(p - p_c)$$

where p_a, p_b, might be complex conjugate and p_c real. These points could be plotted in the p-plane as in Fig. 5,

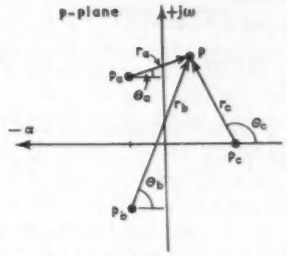

Fig. 5 Representation of $F(p) = (p - p_a)(p - p_b)(p - p_c)$ in the p-plane

and the value of the function for any value of p determined by direct measurement of individual factors in the plane together with the normal complex number multiplication. If magnitude and phase form is used, which is normally more convenient, then

$$F(p) = |F(p)|; \ \angle F(p)$$

and

$$|F(p)| = |p - p_a||p - p_b||p - p_c| = r_a r_b r_c$$

$$\angle F(p) = \angle(p - p_a) + \angle(p - p_b) + \angle(p - p_c) = \theta_a + \theta_b + \theta_c$$

Ratios of polynomials: poles and zeros

The principles just developed may be extended easily to the graphical interpretation of a ratio of polynomials of the form

$$T(p) = \frac{(p - p_a)(p - p_b) \ldots\ldots}{(p - p_1)(p - p_2) \ldots\ldots} = \frac{N(p)}{D(p)}$$

by plotting numerator and demoninator roots in the plane as in Fig. 6,

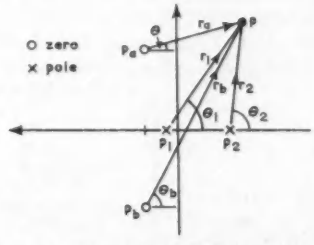

Fig. 6 Pole-zero pattern in the p-plane from a ratio of polynomials

and $$T(p) = \frac{r_a r_b \ldots}{r_1 r_2 \ldots} \qquad \angle T(p) = \theta_a + \theta_b + \ldots - (\theta_1 + \theta_2 + \ldots)$$

where angles for the denominator factors are taken in the negative sense by normal complex division rules.

The graphical representation shows that as the independent point p approaches any numerator factor, say p_a, the line length corresponding to the factor $(p - p_a)$ approaches zero, and hence

$$T(p_a), \ T(p_b), \ldots\ldots = 0$$

these points being termed the *zeros* of $T(p)$. Similarly if p approaches any denominator factor it can be seen that

$$T(p_1),\ T(p_2),\ldots\ldots = \infty$$

and these points are termed the *poles* of $T(p)$. It is conventional to mark zeros with a circle and poles with a cross in the plane.

As an example the transfer

$$T(p) = \frac{(p-1)}{(p^2+2p+5)} = \frac{(p-1)}{(p+1+j2)(p+1-j2)}$$

is plotted as a pole-zero pattern in Fig. 7, and may be evaluated at the point $p = 1 + j1$ to give

$$|T_{(1+j1)}| = 1/(\sqrt{5}\times\sqrt{13});\ \angle T_{(1+j1)} = +90^\circ - 56^\circ + 27^\circ = +61^\circ$$

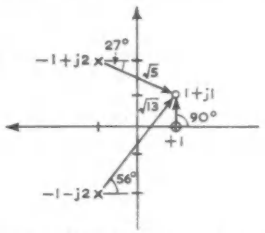

Fig. 7 Evaluation of $T(p) = (p-1)/(p^2+2p+5)$ at $p = 1 + j1$

Multiple-order poles and zeros

Although only first-order poles and zeros have been considered, repeated factors may occur and give rise to multiple-order poles or zeros.

Since $|(p-p_1)^n| = |p-p_1|^n$; $\angle(p-p_1)^n = n\angle(p-p_1)$

a multiple-order pole or zero can easily be handled by raising the magnitude to the appropriate power and multiplying the phase angle. For example, if

$$T(p) = \frac{p}{(p+1)(p+3)^2}$$

the pole-zero pattern is as plotted in Fig. 8, and the function may be evaluated at $p = -2 + j1$ to give

$$|T_{(-2+j1)}| = \frac{\sqrt{5}}{\sqrt{2}(\sqrt{2})^2} = \frac{\sqrt{5}}{4};$$

$$\angle T_{(-2+j1)} = 153^\circ - 135^\circ - 3\times 45^\circ = -117^\circ$$

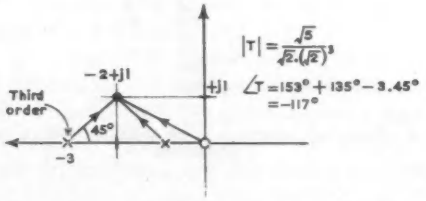

Fig. 8 Evaluation of $T(p) = p/(p+1)(p+3)^2$ at $p = -2 + j1$

The constant multiplier

It is important to note that a direct measurement in the p-plane evaluates a factor of the form $(p - p_j)$, the significant fact being that the coefficient of p is *unity*, and factors must be converted into this form for direct interpretation in the plane. The function

$$F(p) = (p\tau+1)$$

has a single zero at $p = -1/\tau$, and direct interpretation of the pattern in the plane as in Fig. 9, gives

$$F(o) = 1/\tau$$

while in fact

$$F(o) = 1$$

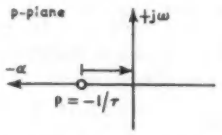

Fig. 9 Direct evaluation of $(p + 1/\tau)$

If the function is converted into the form

$$F(p) = \tau(p+1/\tau)$$

then

$$F(o) = 1$$

Function values along the imaginary axis: frequency response

Along the imaginary axis in the p-plane

$$p \equiv j\omega$$

hence a general transfer function

$$T(p) = N(p)/D(p)$$

becomes

$$T(j\omega) = N(j\omega)/D(j\omega)$$

and the value of the function along the imaginary axis gives the normal *frequency response* of the system in question. This interpretation gives a direct connexion between pole-zero patterns and frequency response, and is one of the most useful qualitative aspects of complex frequency analysis since it enables many general features of frequency response variation to be foreseen easily in terms of pole-zero-pattern variation in the plane.

A single-time-constant system

For the case of a simple *RC* circuit, or the displacement transfer of a spring-dashpot system, as in Fig. 10,

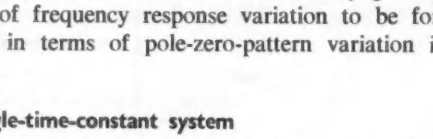

Fig. 10 Systems yielding single-pole transfer functions

the individual differential equations relating input and output become

$$C_1R_1\frac{de_0}{dt} + e_0 = e_1\ ;\ \left(\frac{D}{K}\right)\frac{dx_0}{dt} + x_0 = x_1$$

and with complex frequency substitutions the transfer functions are

$$\frac{E_0}{E_1}(p) = \frac{1}{1+pC_1R_1}\ ;\ \frac{X_0}{X_1}(p) = \frac{1}{1+pC/K}$$

both being of the general form

$$T(p) = \frac{1}{1+p\tau} = \left(\frac{1}{\tau}\right)\frac{1}{(p+1/\tau)}$$

corresponding with a single time constant, and characterized by a pole on the negative real axis at $p = -1/\tau$. The p-plane pattern is shown in Fig. 11, and the general form and salient features of the frequency response are

evident from the pattern. As the frequency is altered the tip of the vector moves along the imaginary axis, and since the vector increases in length continuously with frequency, the magnitude of the transfer will fall steadily. In particular when

$$\omega = 1/\tau$$

then

$$|T| = \left(\frac{1}{\tau}\right)\frac{1}{\sqrt{2}/\tau} = 0{\cdot}707\ ;\ \angle T = -\pi/4$$

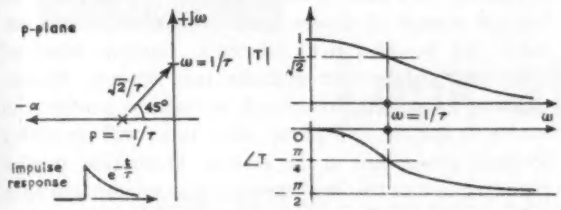

Fig. 11 Frequency response for a single-pole transfer function

The phase will lag by an angle increasing with frequency, and as $\omega \to \infty$ the phase approaches a limiting value of $-\pi/2$.

In addition to the frequency response information that can be obtained, the presence of a pole at $p = -1/\tau$ shows that the transfer has a single natural mode of the form $e^{-t/\tau}$. This would be the impulse response since $p = -1/\tau$ is the solution of the original differential equation in the absence of a continuous input, if a complex frequency form of natural mode is anticipated.

Constant phase and magnitude patterns

In the previous example of a single pole, a phase and magnitude characteristic has been considered along the imaginary axis to yield the normal frequency response. For any value of p a magnitude and phase value can be obtained, and it is possible to trace out lines for which magnitude or phase are constant to form a network of lines covering the entire plane.

Assuming that for a general transfer $T(p)$ the magnitude and phase have been obtained at some point p_j, as

$$|T(p_j)| = T_j\ ;\ \angle T(p_j) = \phi_j$$

a path could be found through p_j such that the magnitude

$$|T(p)| = T_j$$

and another path could be found through p_j such that the phase

$$\angle T(p) = \phi_j$$

to give constant-phase and constant-magnitude lines through p_j as in Fig. 12.

In the immediate vicinity of a pole, say p_i, of the transfer

$$T(p) = \frac{(p-p_a)(p-p_b)\ldots\ldots}{(p-p_i)(p-p_z)\ldots\ldots}$$

the function may be approximated as

$$T(p)_{p\to p_i} \simeq \frac{R_i}{(p-p_i)} = \frac{R_i}{re^{j\theta}}$$

where

$$R_i = \frac{(p_i-p_a)(p_i-p_b)\ldots\ldots}{(p_i-p_z)(p_i-p_3)\ldots\ldots} = |R_i|\ ;\ \angle R_i$$

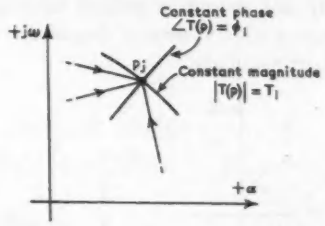

Fig. 12 Constant-phase and constant-magnitude lines for the transfer function T(p) through p_j where $T(p_j) = |T_j|\angle\phi_j$

the approximation being based on the assumption that all vectors *other* than $(p-p_i)$ are substantially constant in magnitude and phase provided that $(p-p_i)$ is small as in Fig. 13, where the length of the vector has been considerably exaggerated for clarity. If the point p traverses a small circle C_i round p_i, r is constant and

$$|T(p)| = R_i/r = \text{constant}$$

The phase is given by

$$\angle T(p) = \angle R_i - \theta$$

which is independent of the size of the circle provided

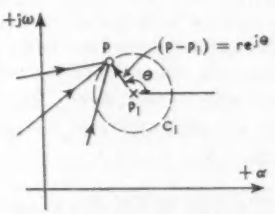

Fig. 13 Approximation in the vicinity of a pole at p_i

it is small. Thus constant-magnitude lines become circles round the pole, and since

$$0 < \theta < 2\pi$$

along C_i a constant-phase line of every value

$$0 < \angle T(p) < 2\pi$$

radiates from the pole.

The constant-phase lines have negative values as θ increases in the conventional positive direction, and the 0° line is orientated at an angle $\angle R_i$ as in Fig. 14a, for the case $R_i = +\pi/4$. The same argument can be carried

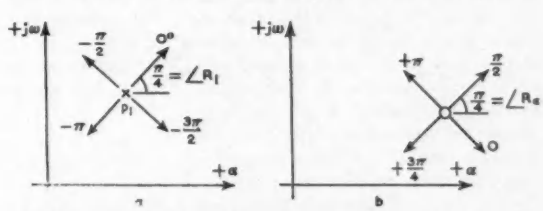

Fig. 14 Constant-phase-line orientation in the vicinity of a pole a or a zero b when the residual angle is $+\pi/4$

through for the immediate vicinity of a zero, yielding circular constant-magnitude lines and radial constant-phase lines; except that for a zero the phase sequence is in the opposite sense, as in Fig. 14b, where the residual angle $\angle R_a$ for the remainder of the function is $+\pi/4$.

In the immediate vicinity of a pole or zero the constant-phase and constant-magnitude lines intersect per-

pendicularly, and though in general regions of the plane the lines have a wide variety of shapes, the intersections are always perpendicular.

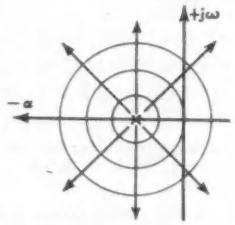

Fig. 15 Constant-phase and constant-magnitude lines for a single pole on the negative real axis

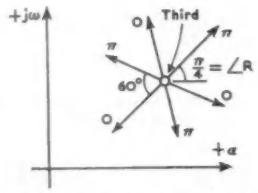

Fig. 16 Constant-phase-line orientation in the vicinity of a third-order zero when $\angle R = +\pi/4$

For the single pole already considered the constant-phase and constant-magnitude line system is very simple, consisting entirely of circles and radial lines as in Fig. 15.

For higher-order zeros and poles the approximation used involves

$$r^n e^{jn\theta} \text{ or } 1/r^n e^{jn}$$

where n is the zero or pole order. Owing to the angle $n\theta$ the phase sequence $0<\angle T(p)<2\pi$ repeats n times equally spaced round the circle. The phase pattern orientation for a third-order zero is shown in Fig. 16, for the case when $\angle R = +\pi/4$.

Three-dimensional representation

It is sometimes useful to visualize pole-zero patterns in a form of three-dimensional representation in which magnitude is plotted vertically on the p-plane, and a vertical section of the figure along the imaginary axis gives the frequency response magnitude. For a single time constant with a pole on the negative real axis Fig. 17 gives the general shape of the three-dimensional figure.

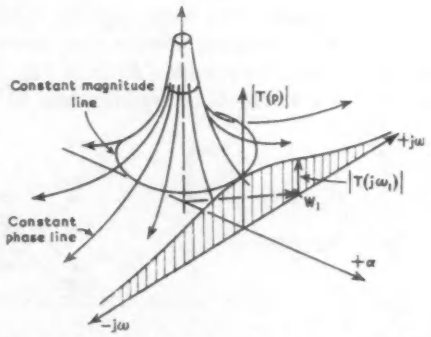

Fig. 17 Three-dimensional representation of a pole on the negative real axis

Stability

Since poles represent values of p which cause the denominator of a function to become zero, these values of p correspond with the natural modes of oscillation of the particular system. The general transfer function

$$T(p) = \frac{(p-p_a)(p-p_b)\ldots\ldots}{(p-p_1)(p-p_2)\ldots\ldots}$$

would have natural modes of oscillation $e^{p_1 t}$; $e^{p_2 t}$; .....

Poles in the left half of the plane correspond with *stable* natural modes, in the sense that the modes represent forms of oscillation which eventually die away after any disturbance has excited them. Poles on the imaginary axis imply constant-amplitude maintained oscillations, and poles in the right half-plane correspond with oscillations increasing in magnitude with time, or *unstable* modes.

Systems may be divided into two categories, those containing only *passive* elements, that is containing no internal source of power, and those containing some *active* (or power-source) elements. Systems obtained from practical passive elements (e.g. springs, masses, resistors, capacitors, inductors), are always stable, with modes in the left half-plane, since there will inevitably be some power loss in the system. Theoretical passive systems (such as the ideal spring-mass system), can have poles on the imaginary axis, since the impulse response is a constant-amplitude oscillation. Systems containing

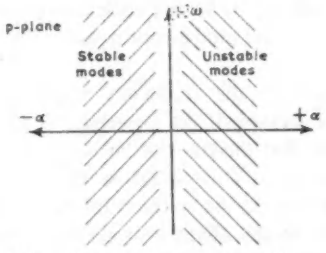

Fig. 18 Division of the p-plane into stable- and unstable-mode regions

active elements (such as power-amplifying closed-loop systems), may have poles anywhere in the plane, and an unstable system is characterized by one or more poles in the right half-plane.

Conclusion

The principle of representing functions or ratios of polynomials as pole-zero patterns in the p-plane having been introduced, the main properties of this form of representation may be summarized as follows:

a A function is completely defined over the plane by its pole-zero pattern, except for a constant multiplier which is not evident from the pattern.

b The magnitude of the function at any point, apart from the constant multiplier, may be obtained by multiplication and division of distances measured or calculated from the plane.

c The value of the phase at any point is obtained by addition and subtraction of angles, and the value is not affected by the constant multiplier.

d A pattern gives rise to a network of lines of constant phase and constant magnitude. The network covers the entire plane, and along the imaginary axis it gives the normal frequency response.

e Poles of the function correspond with natural modes of oscillation, and for stability must be in the left half-plane, with a limiting condition of maintained oscillation on the imaginary axis.

This news-letter from our special correspondents in the United States includes a detailed discussion of Lyapunov's second method for non-linear systems

Look at America

This month: variable-speed drive—hydraulic-valve efficiency—non-linear systems

Variable-speed drive

Although hydraulic and electric drives are widely used for the accurate and continuous control of power in mechanical systems, little use has been made of mechanical drives. In applications where severe environmental conditions and performance requirements prohibit the use of hydraulic and electric drives, mechanical drives are being given serious consideration. Obvious advantages of completely mechanical drives are the elimination of one or more energy conversions and the possible reduction of system complexity.

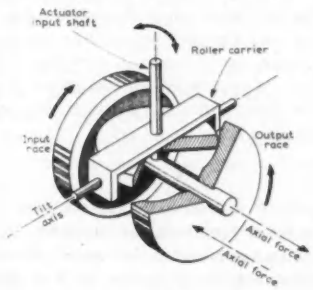

Fig. 1 Cut-away view of 'toric' transmission

An interesting mechanical actuator, that is claimed to have the performance potential to fulfil high-power control applications requiring reasonable dynamic response and high accuracy, is the 'toric' transmission combined with a single or dual differential split drive. Figs. 1 and 2 show respectively the 'toric' transmission and a complete actuator. If used as the drive of a position-control system, the actuator would function as an integrator in the same way as would a hydraulic or electric motor. The condition of zero velocity of the actuator output shaft occurs at a one-to-one speed ratio of the transmission (i.e. input race speed equals output race speed). Clockwise and counterclockwise rotation of the output shaft is achieved by varying the transmission speed ratio up or down from unity.

The basic transmission consists of two toroidal races separated by three symmetrically spaced rollers. An axial force squeezes the assembly together so that torque is transmitted through friction contacts. If the input race is driven at constant speed the roller tilt angle determines the output speed. The roller is mounted through a universal bearing to a centre shaft connected to the roller carrier. Rotating the carrier about the tilt axis gives control of the ratio. A mechanical force-balance system (employing off-set springs) provides the control mechanism necessary to position the roller in a new tilt position.

Harned, *et al* (*1*) have made a detailed theoretical and experimental study of the dynamic operating characteristics of the toric transmission. Reasonably good correlation between theory and experiment should provide a basis for rational design.

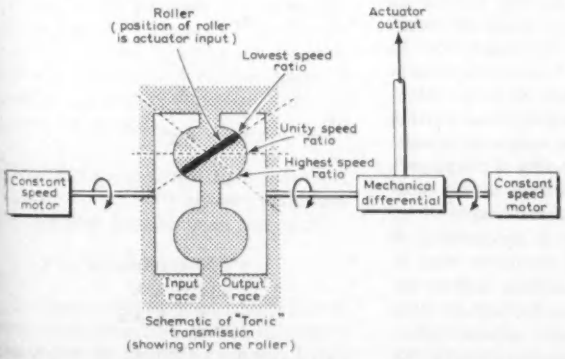

Fig. 2 'Toric' transmission incorporated in mechanical actuator. Output of the actuator is zero when transmission rollers are in the 'unity speed ratio' position

Power efficiency of hydraulic systems

Primary concern in the design of high-performance valve-controlled hydraulic systems for modern airborne applications has been the production of low-weight and small-volume systems that will satisfy specified dynamic response and stability requirements. Naturally, improvement of the power efficiency of such systems results in a reduction in size and weight of the entire system. However, exploitation of possible power efficiency improvements, insofar as servo-valve design is concerned, has been slow compared to other developments. It must be admitted, of course, that the power efficiency of a valve-controlled system is inherently poor. By its very nature and function, the control valve is a power dissipating device.

Conventional control valves are so constructed that the orifice area of the valve varies according to an input signal. The controlled flow from the valve can be shown to depend not only on the input signal, but also on the load pressure (i.e., pressure drop across the actuator) and supply pressure. In many applications, both the load pressure and supply pressure can change considerably during a particular control process. Therefore, referring to the valve charac-

teristics of Fig. 3, it is seen that the valve gain (i.e. flow variation per unit input signal variation) can also change considerably. It is frequently hard to satisfy both dynamic response and stability requirements when large variations in valve gain occur.

A constant-gain valve, sometimes called a 'gain compensated' or 'flow control' valve, was described in the September edition of *Look at America*. This new valve was developed by Dr S.-Y. Lee of the Massachusetts Institute of Technology in co-operation with Pesco Products Division, Borg-Warner Corporation. A constant-gain control valve is one in which the output flow is solely dependent upon the input signal (within the useful range of the valve). See Fig. 4 for typical valve characteristics.

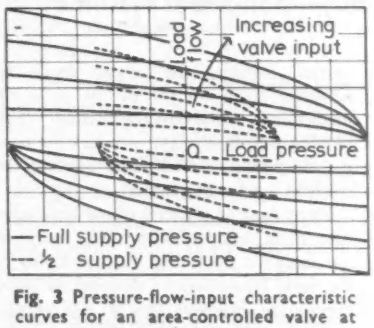

Fig. 3 Pressure-flow-input characteristic curves for an area-controlled valve at two supply pressures

In a paper (*2*) presented at the recent J.A.C. Conference, Dr S.-Y. Lee discusses the power efficiency of a hydraulic control system by use of the constant-gain valve. For a system employing an ideal closed-centre four-way valve (area or flow control) and a 100% efficient actuator, the instantaneous efficiency is given by:

$$\eta = \frac{\text{hydraulic power output}}{\text{hydraulic power input}} = \frac{P_L Q_L}{P_S Q_L} = \frac{P_L}{P_S}$$

where P_L = load pressure, Q_L = load flow, and P_S = supply pressure.

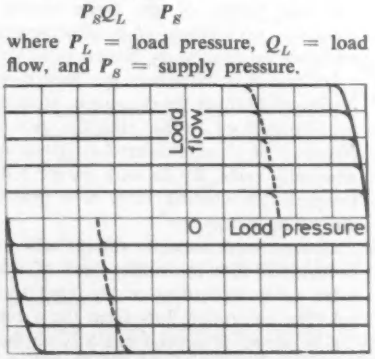

Fig. 4 Pressure-flow-input characteristic curves for a flow-feedback valve at two supply pressures

Thus, for two different position control systems performing the same control function, the one with the higher pressure is seen to have the higher instantaneous efficiency. A comparison of the constant-gain valve and the area-control valve characteristics shows that it is possible to use a higher load pressure (and a smaller actuator area) with the former for any one of several actuator loads (e.g. coulomb friction, viscous friction, spring, inertia, and constant force). Thus better power efficiency usually results with the constant-gain valve.

Lyapunov's second method for non-linear systems

Sustained interest in non-linear systems, and the increasing need to understand more about their dynamic behaviour, have resulted recently in more general use of the second method of Lyapunov (*3*) in the U.S. The Russian pre-eminence in theoretical work on non-linear systems has been well recognized for many years, yet is is only quite recently that an appreciable segment of professional engineers and scientists has gained sufficient familiarity with this theoretical work to be able to use it effectively on non-linear control systems. The second method of Lyapunov is important in control systems work because it deals both with problems of system stability and system speed of response. Several excellent papers are now available in English (*4, 5, 6*).

In an overall sense, the second method provides an extremely general stability criterion for dynamic systems, and the results obtained from application of the criterion can be extended to evaluate a system's transient behaviour. Some obvious advantages of the method are: (1) it generally does *not* require the assumption of linearity or stationarity in order to be applied; (2) it is not necessary to solve the differential equations of the system in order to determine stability, nor is it necesssary to obtain the characteristic equation of the system. Similarly, transient behaviour can be estimated without actually solving the system equations; (3) a fundamental, non-arbitrary basis is directly available for the stability evaluation of all non-linear control systems.

A less attractive aspect is that the method does not generally provide an explicit, systematic procedure for determining system stability, except for the restricted case of linear, stationary systems. It is noted that for these restrictions the Routh-Hurwitz stability criterion also applies, but it is a commendation of the generality of Lyapunov's method that its application in this situation gives rise to a set of conditions required for stability that are identical to the Routh-Hurwitz inequalities. That is, the Routh-Hurwitz criterion can be derived from Lyapunov's method. The method will invariably require ingenuity and intuition on the part of the user, analogous to that required in the solution of most differential equations. Usually there is no explicit procedure for obtaining a solution, but if one is assumed, its validity can be readily checked.

It is parenthetically noted here that the 'first method' deals with stability problems through the explicit solution of the linearized system equations.

A description of Lyapunov's second method requires the use of the vector 'state' of the dynamic system, that is, a representation of system behaviour in terms of a vector or matrix set whose components are the variables and their derivatives,

$$\mathbf{X} \equiv \begin{vmatrix} X_1 \\ X_2 \\ \cdot \\ \cdot \\ \cdot \\ X_n \end{vmatrix}$$

Where any of the X's may be time derivatives of others.

Then it is always possible to describe a system by the vector differential equation

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathbf{X} \equiv \dot{\mathbf{X}} = \mathbf{f}(\mathbf{X}, \mathbf{U}(t), t)$$

$\mathbf{U}(t)$ is the forcing function, which is assumed to be identically zero (the system is then called free or unforced). Then

$$\dot{\mathbf{X}} = \mathbf{f}(\mathbf{X}, t)$$

The vector function $\mathbf{f}$ specifies the system, and the presence of t as one of the independent functional variables means that the system is not stationary. For a free, linear, stationary system, the representation is

$$\dot{\mathbf{X}} = \mathbf{F}\mathbf{X}$$

where $\mathbf{F}$ is the matrix of coefficients of the set of simultaneous equations. As an illustration of these definitions, the non-linear, stationary system in Fig. 5 can be represented by

$$\dot{X}_1 = \mathrm{f}_1(X_1) + \mathrm{f}_2(X_2)$$
$$\dot{X}_2 = X_1 + aX_2$$

or

$$\dot{\mathbf{X}} = \begin{vmatrix} \dot{X}_1 \\ \dot{X}_2 \end{vmatrix}$$

$$\mathbf{f} = \begin{vmatrix} \mathrm{f}_1 & \mathrm{f}_2 \\ 1 & a \end{vmatrix}$$

$$\mathbf{X} = \begin{vmatrix} X_1 \\ X_2 \end{vmatrix}$$

or

$$\mathbf{X} = \mathbf{f}(\mathbf{X})$$

Note that the $\mathbf{f}$ matrix is a functional or operational matrix.

Using this notation, and defining

$$\mathbf{X}' \equiv \text{transpose of } \mathbf{X}$$
$$||\mathbf{X}||^2 \equiv \mathbf{X}'\mathbf{X}$$
$$||\mathbf{X}||^2_{\mathbf{A}} \equiv \mathbf{X}'\mathbf{A}\mathbf{X},$$

then Lyapunov's theorem can be stated:

Theorem

Consider the free, non-linear, non-stationary system

$$\frac{d\mathbf{X}}{dt} = \mathbf{f}(\mathbf{X}, t);\ \mathbf{f}(\mathbf{0}, t) = \mathbf{0}$$

If:

1. There exists a scalar function $V(\mathbf{X}, t)$ with continuous first partial derivatives with respect to $\mathbf{X}$ and t such that $V(\mathbf{0}, t) = 0$

and,

2. $V(\mathbf{X}, t)$ is positive definite, i.e., there exists a continuous non-decreasing scalar function α such that $\alpha(0) = 0$ and $0 < \alpha(\|\mathbf{X}\|) \leqslant V(\mathbf{X}, t);\ t \neq 0\ \mathbf{X} \neq 0$

and,

3. There exists a continuous scalar function γ such that $\gamma(0) = 0$ and $\frac{dV}{dt}$ along the motion starting at $\mathbf{X}$, t satisfies $\frac{d}{dt}V(\mathbf{X}, t) \equiv \dot{V}(\mathbf{X}, t) \leqslant -\gamma(\|\mathbf{X}\|) < 0$; where $t \neq 0,\ \mathbf{X} \neq 0$

and,

4. There exists a continuous non-decreasing scalar function β such that $\beta(0) = 0$ and

$$V(\mathbf{X}, t) \leqslant \beta(\|\mathbf{X}\|)$$

and,

5. $\alpha(\|\mathbf{X}\|) \to \infty$ as $\|\mathbf{X}\| \to \infty$

Then:

The equilibrium state, $\mathbf{X}_e = \mathbf{0}$, is uniformly, asymptotically stable in the large, i.e., the system will eventually return to $\mathbf{X}_e$ even for very large disturbances. $V(\mathbf{X}, t)$ is called a Lyapunov function of the system.

This is a statement of Lyapunov's second method in its most general form. A somewhat less rigorous but more digestible statement would be: if the function $V(\mathbf{X}, t)$ can be found subject to the conditions 1–5 above, then stability of the system is assured. The difficulty, of course, is that no explicit means of finding $V(\mathbf{X}, t)$ is provided. That is where ingenuity, cleverness, and just plain guessing come into play. For certain simple systems it is often possible to use the energy of the system as a Lyapunov function, but this is by no means generally applicable.

Owing to the inclusion of non-stationary systems, the statement of the theorem was made quite cumbersome. If only stationary systems are considered, a greatly simplified statement of the theorem is possible.

Corollary A

Consider the free, stationary, non-linear system

$$\dot{\mathbf{X}} = \mathbf{f}(\mathbf{X});\ \mathbf{f}(\mathbf{0}) = \mathbf{0}$$

If:

1. There exists a scalar function $V(\mathbf{X})$ with continuous first partial derivatives and $V(\mathbf{0}) = 0$

and

2. $V(\mathbf{X}) > 0;\ \mathbf{X} \neq \mathbf{0}$

and

3. $\dot{V}(\mathbf{X}) < 0;\ \mathbf{X} \neq 0$

and

4. $V(\mathbf{X}) \to \infty$ as $\|\mathbf{X}\| \to \infty$

Then:

Stability in the large is assured and $V(\mathbf{X})$ is a Lyapunov function of the system.

For the very special case of free, linear, stationary systems, we have the only situation now known in which it is possible actually to calculate the Lyapunov function directly.

Corollary B

Consider the free, linear, stationary system

$$\dot{\mathbf{X}} = \mathbf{F}\mathbf{X}.$$

Stability is assured *if* there exists a symmetrical, positive definite matrix $\mathbf{P}$ that solves the equation

$$\mathbf{F}'\mathbf{P} + \mathbf{P}\mathbf{F} = -\mathbf{Q}$$

where $\mathbf{Q}$ is any symmetrical positive-definite matrix. Since $\mathbf{F}$ is known and $\mathbf{Q}$ is arbitrarily chosen (it can be the unit matrix), it is possible to solve for the elements of $\mathbf{P}$ in a relatively straightforward manner by actually multiplying out the matrix equation. Doing so, however, requires the solution of $\frac{n}{2}(n+1)$ simultaneous algebraic equations, where n is the order of the system. The requirement that $\mathbf{P}$ be positive-definite gives rise to the Routh-Hurwitz inequalities as mentioned before. Also, a Lyapunov function for the system is

$$V(\mathbf{X}) = \|\mathbf{X}\|^2\mathbf{P}$$

If the ratio is formed,

$$\eta = \left[\frac{-\dot{V}(\mathbf{X}, t)}{V(\mathbf{X}, t)}\right]_{\min}$$

then it is seen that η is a measure of the speed of response, since V is analogous to the distance of the state variable from the origin, and $\dot{V}$ is analogous to the speed of the state variable. $1/\eta$ can be interpreted as the largest time constant over the region of state space. Hence finding a Lyapunov function also allows evaluation, in a unified fashion from system to system, of transient behaviour. As before, the specific result when the restrictions of linearity and stationarity are applied is explicit: η is the minimum eigenvalue of $\mathbf{P}^{-1}$ where $\mathbf{P}$ is as defined previously. The time constants found in this way are equal to one-half the value of those normally found by actual solution of the equation, as a result of the different definition of time constant in each case.

Application of the second method to certain non-linear systems has yielded readily useful results as reported in reference (*3*). One interesting sidelight is a rigorous justification of the technique of linearization. It is shown that if a Lyapunov function can be obtained for a linearized set of equations, then it is also a Lyapunov function for the original non-linear equations (which may also be non-stationary). Hence, if the linearized equations are stable, so also are the non-linear equations for small disturbances.

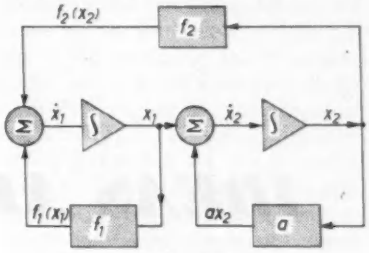

Fig. 5 A non-linear system

In application to the system of Fig. 5, the result is obtained that stability exists if

$$4\alpha f_1'(X_1) - [1 + f_2'(X_2)]^2 \geqslant \varepsilon^2 > 0$$

and

$$f_1'(X_1) \leqslant -\varepsilon < 0$$

where

$$f' = \frac{df}{dt}$$

and $\varepsilon > 0$ is an arbitrary constant.

This serves to illustrate the very practical results that the method can yield. As Lyapunov functions are discovered for different systems, they can be catalogued, in a way similar to that in which integrals and solutions to differential equations are tabulated. There is some hope that computing machines may prove helpful in assisting in the search for suitable functions.

Your American Correspondents

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IDEAS APPLIED . . .

. . . to POSITION

Digital indication of shaft rotation by use of synchros

by T. ROBERTS, Research Laboratories of The General Electric Co. Ltd, Wembley, Middlesex

A method of using conventional electrical components to give a digital representation of the angular position of a shaft was described by the writer at a recent meeting in London of the Society of Instrument Technology. Among other advantages, it is claimed that the system — comprising mainly synchros, transformers, relays and solid-state components — should be more reliable than digitizers using coded disks in conjunction with photoelectric or mechanical pick-offs.

The basis of the method is to convert the three stator voltages of a synchro transmitter into five voltages having amplitude distributions, relating to rotor shaft angle, which are spaced 72° apart from one another. By detecting whether each of these five voltages is in phase or antiphase with the supply to the rotor, a five-channel binary code is produced which has unique combinations for each 36° segment of the synchro rotor movement. Successive synchros geared 10:1 to one another can be used to give multi-decade code combinations.

Fig. 1.1 illustrates the method of obtaining the five voltages from one synchro. Each of the three outputs from the synchro is taken to the primary of one of three transformers. The primaries are thus energized by the voltages V_1, V_2 and V_3 which have equal maximum amplitudes, but these occur at shaft angles 120° apart from each other.

Each transformer has three secondary windings, as shown in Fig.1.1.

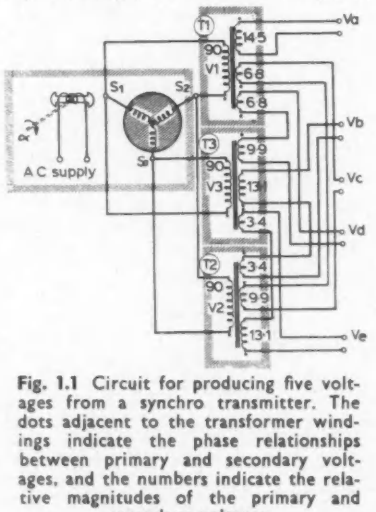


Fig. 1.1 Circuit for producing five voltages from a synchro transmitter. The dots adjacent to the transformer windings indicate the phase relationships between primary and secondary voltages, and the numbers indicate the relative magnitudes of the primary and secondary voltages

These windings have different numbers of turns, the relative magnitudes of the voltages developed in them being represented by the numbers on the

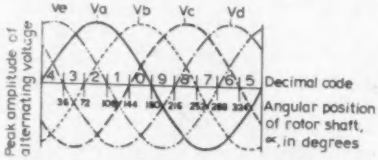


Fig. 1.2 Amplitude variations of the five outputs in relation to synchro shaft position

diagram. These voltages are combined in pairs to give the five output voltages V_a, V_b, V_c, V_d, V_e, which have equal maximum amplitudes; these occur at shaft angles 72° apart from each other as shown in Fig. 1.2, the sinusoidal nature of the amplitude variation being due to the distribution of the synchro stator windings.

Each of the five voltages is fed to its own phase discriminating circuit, where its phase is compared with that of the supply to the synchro rotor. The resultant signal is passed to its own bi-stable transistor circuit which operates a relay if the particular voltage is in phase with the supply, and releases it when it changes to antiphase: each voltage will be in phase for a particular 180° of shaft rotation, and out of phase for the remaining 180°. The particular relay combinations are given in Fig. 1.3, from which it is seen that each 36° sector is represented by a unique code combination, and the change from one combination to the next is always achieved by a change in one relay state only. This 'one at a time' change characteristic is of importance, since if more than one change were required at a time it would be difficult to ensure that the operations occurred simultaneously.

Thus a synchro rotor position can be represented by discrete output signals as being in one of ten positions, and these signals may conveniently be used to operate a counter numbered 0 to 9. A single synchro used in this way is very limited in its applications, but by gearing a number of such synchros to a shaft through a series of 10:1 gear trains, and using their outputs to operate successive digits of a counter, a useful multi-decade readout can be obtained.

A difficulty, common to some other types of digitizer, arises when this is done. When two digits are required to change simultaneously, as when changing from 19 to 20, some pre-

SYNCHRO ROTOR SHAFT ANGLE IN DEGREES	RELAY STATES: 1 = OPERATED 0 = RELEASED A	B	C	D	E	DECIMAL NUMBER
0	0	0	0	1	1	5
36	1	0	0	1	1	4
72	1	0	0	0	1	3
108	1	1	0	0	1	2
144	1	1	0	0	0	1
180	1	1	1	0	0	0
216	0	1	1	0	0	9
252	0	1	1	1	0	8
288	0	0	1	1	0	7
324	0	0	1	1	1	6
360	0	0	0	1	1	5

Fig. 1.3 Code resulting from operation of relays associated with one synchro

caution is necessary to prevent possible false combinations (10 and 29) from being presented, as mechanical gearing cannot be made with sufficient accuracy to guarantee simultaneous change-over. However, a relatively simple electrical solution to this problem is possible in this case. Bias windings (not shown in Fig. 1.1) are included on the primary side of the three transformers connected to each of the synchros, with the exception of the synchro representing the least significant digit. These bias windings are capable of connexion in one of two ways, to simulate either a 9° advance or a 9° retardation of the rotor from its true position. The mode of connexion is controlled from the following (i.e. next least significant) synchro, so that when this synchro is 'reading' digits 5 to 9 inclusive a retardation is simulated, and when it is 'reading' 0 to 4 inclusive an advance is simulated. Thus, when the digit representing the position of a synchro changes from 9 to 0, the next more significant synchro experiences a simulated instantaneous advance of 18°. This is more than sufficient to 'swamp' any mechanical and electrical errors in the system, and ensure virtually simultaneous change-over.

Several four-decade digitizers using size-11 synchros and one using size-08 synchros and operating at 400 c/s have been made and have operated satisfactorily with their decoding circuits. These circuits have been made up on printed wiring boards. The five phase-discriminating and bi-stable circuits comprising one decade are contained on one board measuring $5\frac{1}{2}$ in $\times$ $6\frac{1}{2}$ in, four such boards being needed for a four-decade digitizer.

As an extension of the method, a circuit arrangement has been evolved so that 100 code combinations may be obtained from one synchro.

. . . to PNEUMATIC CONTROLLERS

Compact bellows mechanism

Shown at the recent Interkama exhibition in Düsseldorf, a pneumatic controller manufactured by J. C. Eckardt A.G. is interesting for its mechanical layout. Though its operating principles are similar to those of other pneumatic controllers, the compact arrangement, shown in Fig. 2.1, permits robust construction and a particularly simple method of proportional band adjustment over a wide range.

Basically, the controller consists of the four bellows, *A*, *B*, *C* and *D* located on a fixed central spigot and attached to the inner surface of the ring *E*; the ring is free to move under the combined action of the forces exerted by the four bellows, and in moving it alters the clearance between its outer surface and the nozzle *N*, which is carried on the arm *F*. Pro-

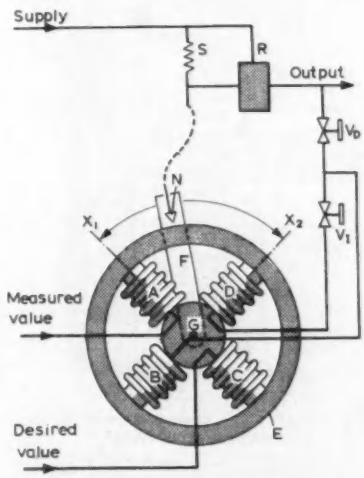


Fig. 2.1 Simplified schematic diagram of connexion to controller. Manual control and auto/manual switching arrangements have been omitted for clarity

portional band adjustment is obtained by rotating the arm *F* about *G*, which is the centre of the ring *E* when the pressures in all four bellows are equal.

IDEAS APPLIED . . .

As in other conventional controllers, the output pressure is taken from an air relay *R* and is equal to the pressure in the line between the restriction *S* and the nozzle *N*, this pressure in turn depending on the clearance between *N* and *E*. Air pressures representing the measured and desired values of the controlled variable are fed to the bellows *A* and *C* respectively. Any difference in these pressures alters the nozzle clearance, causing a change in the output pressure, which is fed back via the derivative valve V_D to the bellows *B*. This produces negative feedback, tending to reduce the relative movement between *N* and *E* produced by the original unbalance. The magnitude of the feedback depends on the position of the arm *F* (proportional band adjustment) and the rate of feedback depends on the setting of the valve V_D (derivative action adjustment). Offset is prevented by the ultimate equalization, via the integral valve V_I, of the pressures in bellows *B* and *D*.

. . to CONCENTRATION

Measurement of liquid conductivity without electrodes

The conductivity of a solution, which is a measure of its concentration, is conventionally found by measuring the resistance between two metal electrodes in a liquid-filled cell. Methods of this kind are unsatisfactory in many applications because of polarization and contamination of the electrodes.

Various indirect methods, not involving direct contact between electrodes and liquid, have recently been developed to overcome these difficulties. One such method, in which the liquid is used to provide electrical coupling between two transformer windings, has been incorporated in an industrial concentration meter recently developed in the U.S.S.R. The coupling provided by the liquid in this arrangement is proportional to its conductivity.

Fig. 3.1 shows the instrument schematically. The primary winding of the transformer T_1 is supplied from a.c. mains. A circuit formed by the liquid in the tube *B* acts as a secondary winding for transformer T_1, and as one of the three primary windings of transformer T_2.

The output from T_2 is taken via the amplifier *A* to the reversing motor *M*, which drives the synchro transmitter

S. One of the outputs from this transmitter supplies a second input to the transformer T_2 through the primary winding P_1, this winding acting in

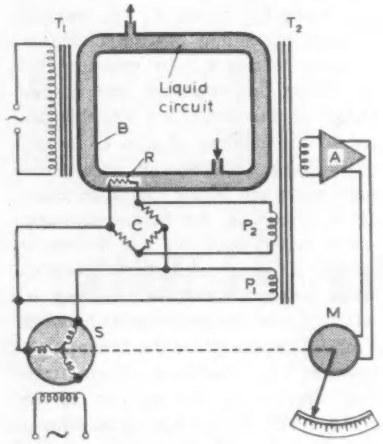


Fig. 3.1 Schematic diagram of conductivity measuring system

opposition to the input from the liquid circuit. The components *A*, *M*, *S* and P_2 are in fact a null-balance system, such that any change in the input from the liquid circuit produces a corresponding change in the input from P_2 and cancels the secondary current. The drive for the indicating mechanism is taken from the motor *M*.

A third transformer input, the winding P_3, is fed from the temperature compensating bridge *C*. This bridge includes the resistance thermometer *R*, which is immersed in the liquid, and is supplied from the same synchro terminals as the winding P_1. Compensation is thus proportional to temperature and to the magnitude of the main input signal.

The use of a synchro in the feedback in the way described has the advantage that, as the relation between its output voltage and rotor position is similar to that between conductance and concentration, a near-linear instrument scale results.

Acknowledgement

The above description is based on an article in a recent issue of the D.S.I.R. publication *Instrument Construction*, being a translation of the Russian journal *Priborostroenie* for December 1959.

Suspended-solids recorder

A new instrument has been developed at the Water Pollution Research Laboratory of the D.S.I.R. for recording the concentration of suspended solids in effluents. It depends, in principle, on the measurement of light scattered by the suspended particles.

Two beams of light, originating from the same source, are directed into a cell containing a sample of the liquid. These two beams are at right angles to each other, and are interrupted by 'chopper' disks rotating at different speeds. One interrupted light beam is directed through the liquid at a barrier-layer photocell. The second beam is directed across the liquid cell, so that only a small proportion of its light, scattered by the suspended particles, is received by the photocell. The output from the photocell is thus made up of two components pulsating at distinct frequencies, with amplitudes proportional to the direct and scattered light respectively. These two outputs may be separated by appropriate filter circuits after amplification.

The ratio of the two signals is a measure of the suspended solids concentration, and may be displayed on a potentiometric recorder. An advantage of this method is that its accuracy is unaffected by variations in the characteristics of the light source and photocell.

. . . to FORCE

Accurate conversion of force to pressure

A force-measuring system now being produced by Solartron is based on equipment patented by the D.S.I.R. An accurate force transducer is used to

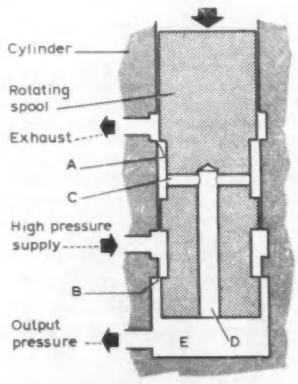


Fig 4.1 Schematic cross-section of force-to-pressure converter

produce a hydraulic pressure proportional to the force, the pressure being used to operate indicators or other receiving equipment. The transducer, which is designed to measure forces up to 1000 lbf, resembles a spool-type hydraulic valve, and works on a similar principle.

Referring to Fig. 4.1, the force is applied axially to the spool, and is converted to a proportional pressure in the chamber *E*. The valve is shown in its equilibrium position. An increase in load will cause the spool to move downwards, opening the annular aperture *B* and allowing high-pressure fluid to enter *E* to restore balance. Similarly, a reduction in load will cause an upward movement of the spool, opening the aperture *A* and the high-pressure fluid in *E* will escape through the drillings *D* and *C* to the exhaust line. The spool is continuously rotated by a small electric motor to reduce friction effects. An output pressure is thus obtained which is proportional to the force, with a claimed accuracy of $\pm 0{\cdot}02\%$.

This output pressure may be measured by any conventional method. The Solartron system uses a servo-operated weighbeam. The pressure signal is taken to a hydraulic jack, incorporating a rotating piston, which converts pressure back to force, and applies the force to a fixed point on the beam. Balance of the beam is achieved by a moving weight, carried on a lead-screw driven by a servomotor. The rotation of the lead-screw is converted to electrical analogue or digital signals as required.

This transducer was originally used by the National Engineering Laboratory of the D.S.I.R. for measuring torque, by measuring the thrust at the end of an arm of known length. Using the system described above, it was possible to mount the sensitive weighbeam equipment in a position remote from the machine developing the torque.

Improved load cell

A sensitive load cell, recently developed at the R.A.E., is claimed to have a number of advantages over the conventional pillar type of cell. Fig. 4.2 shows the principle of the design. The load is transmitted through two concentric tubes, to which the strain gauges are bonded, the inner tube being in tension and the outer in compression.

This arrangement allows a higher diameter/height ratio than is possible with a pillar-type cell of similar sensitivity, and makes the cell more tolerant of side thrust. A slightly-modified version can, in fact, accept side thrusts up to one fifth of the cell capacity without decrease in accuracy. Protec-

tion against overload is provided by the small clearance between the lower end of the inner tube and the base of the cell, this clearance closing up on overload so that thrust is transmitted directly from the tube to the base plate. This feature permits overloads up to ten times the capacity of the cell without damage to the strain gauges.

The strain gauges are bonded side by side on the inner tube to cover

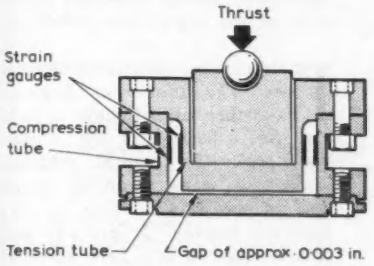


Fig. 4.2 Cross section of load-cell

its circumference, and the same number of gauges is attached to the outer tube. The strains in the two tubes may be made equal by making their cross-sectional areas equal.

A full description of this load cell is given in the Ministry of Aviation publication R. & M. No. 3153.

. . . to DATA HANDLING

Pulse-duration-modulated transmission

A data acquisition system introduced by the Electro-Logic Corporation of America* converts electrical analogue signals into pulse-duration-modulated signals before transmission to central data processing equipment. The p.d.m. (pulse - duration - modulated) signals from a number of primary measuring elements, such as thermocouples or strain gauges, are transmitted serially along a single line to a converter. This converter, which common to all the measuring points, produces digital signals from the p.d.m. pulses.

The system is claimed to have several advantages over systems which use direct analogue to digital conversion. In particular, it eliminates low-level d.c. amplifiers and the commutation or multiplexing of the analogue input signals.

Each measuring element has its own signal converter, known as a 'transponder'. These 'transponders' normally accept a d.c. input signal having a full-scale range of more than 10 mV, though lower ranges are possible. During the operating cycle, which is controlled by external units, the input signal is applied for a set time period to a winding on a square loop magnetic core; a flux level proportional to the input is thus established in the core. Power is then applied to a second winding to saturate the core. This takes a finite time, the length of which depends on the flux-level already established in the core by the input signal. The output pulse from the transponder, which is in the range 3·5 to 13·5 ms, is derived from a measurement of this time period. After each output pulse, the core flux is reset to a fixed residual level before the input signal is reapplied, the normal rate of repetition of the operating cycle being 150 c/s. The sensitivity of the unit may be varied by altering the duration of the period during which the input signal is applied.

'Transponders' are designed to work in a data transmission system of the type shown in simplified form in Fig. 5.1. Each 'transponder' is 'interrogated' in turn by a pulse which starts its operating cycle. The resulting output pulses are taken via a buffer unit (which prevents interaction between the individual measuring circuits) and used to 'gate' the signal from a

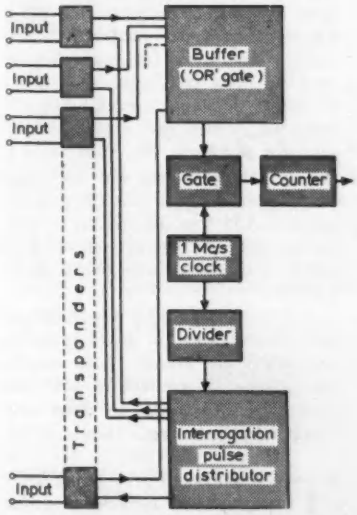


Fig. 5.1 Block diagram of essential units of pulse-duration-modulated data transmission system

1 Mc/s clock. The signals are thus converted to a series of groups of 1 Mc/s pulses which may then be counted and converted to a digital signal in binary (or other) code. A signal from the 1 Mc/s clock is also fed, via a divider, to the interrogation-pulse distributor.

The space occupied by each transponder unit is of the order of 1 in³. A temperature controlled environment is required to maintain high accuracy (which is claimed to be 0·1% under rigidly controlling conditions). Reproducibility is claimed to be ±0·1%, and the natural linearity of ±3% can be corrected to ±0·1% by extra circuitry if required.

Digital print-out unit

An example of how a conventional electrical device can be adapted to work in conjunction with a digital computer system is provided by a digital print-out unit, designed by the

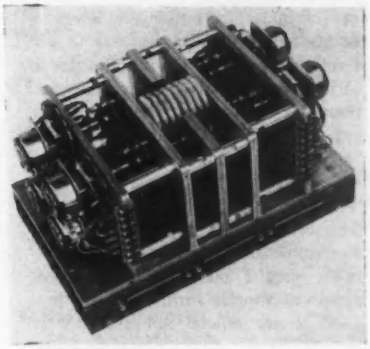


Fig. 5.2 Simple print-out device

Electronics Division of Armstrong Whitworth Aircraft.

The unit is designed to provide an eight-character in-line print-out. The characters to be printed are selected by simultaneously setting up eight coaxially mounted nylon print wheels, each of which carries twelve raised characters around its circumference. The wheels are driven by Ledex rotary relays controlled by transistor amplifiers. Character selection is by a 'one out of twelve' code on the twelve input wires associated with each print wheel. The maximum setting-up time is 600 ms.

Switch facilities are provided to operate any single print wheel, or a number of print wheels, in any combination. The operation may be controlled either from a remote source, such as a computer, or locally from a switch. The control unit is fully transistorized and printed-circuit technique is employed to facilitate rapid servicing and replacement.

* Marketed in the U.K. by Scientific Furnishings Ltd, Poynton, Cheshire

Pick-off

by 'UNCONTROLLED'

THE TERROR of their schooldays will return to some engineers now that the B.S.I. has revised its specification for letter symbols, signs and abbreviations; for the problem of where to put that wretched *g* is coming up in a disguised form. According to the B.S.I. amendment, identically-named units of mass and force will henceforward be distinguished from each other by tacking an 'f' on to the abbreviations for force units. Thus pounds mass will be written 'lb' as before, but pounds force become 'lbf'. I have already met more than one qualified engineer foxed by the question of whether pressure measures in units of lb/in^2 or lbf/in^2! The innovation seems a bodge to me—the proper way to differentiate between mass and force is to use absolute units (e.g. pounds and poundals, or slugs and pounds).

I am delighted to see that things like 'sq.m' and 'cu.m' are now thrown out altogether in favour of 'm^2', 'm^3' and so on. The abolition of 'sec' for seconds will probably be a bit worrisome at first, though (like everybody else) I take naturally to the approved shorter form in 'c/s.' It is good to see official abbreviations at last for longer time units, but I find the choice of 'a' for years rather unhappy. I suppose it is consistent with 'p.a.' for per annum, but I don't think the classical descent is sufficient justification: still, we shall probably get used to it. I am quite pleased with B.S.I.'s preference for 'μm' (micrometres) rather than 'μ' (microns)—the latter has always seemed out of place in the hierarchy of units.

I wonder how many engineers realize that the degree centigrade was abolished in 1948 (by the Conférence Générale des Poids et Mesures), and that the proper name nowadays is 'degree Celsius'? The new B.S. is certainly cleaning up temperature units, for it is quite firm about the distinction between *point* temperatures and temperature *intervals*. Point temperatures are still denoted by the old abbreviations (like °C), but temperature differences are written 'degC', 'degF', etc. I hope this usage will catch on quickly.

AS EVER, Sir Harold Hartley had many illuminating things to say when he addressed the Institution of Gas Engineers a few weeks ago. His theme was the choice of subjects for research and development, and he played repeatedly on the importance of hunches. 'While the economic aspects of research and development must always be the governing criterion of policy, I am frankly sceptical of schemes for the numerical appraisal of the relative merit of different projects. The ultimate decision must be a matter of judgment trained by previous experience and seen at its best in individuals, like Charles Kettering of General Motors, gifted with intuition. I remember Josiah Stamp saying to me when I went to Euston in 1930: "Remember, when you were writing a paper for the Royal Society you were trying to be 100 per cent right, in the L.M.S. you are doing well if you are 60 per cent right", and 60 per cent is a high target in research and development. Kettering was critical of educational systems that taught the danger of failure. Failure to him was an opportunity to find its cause. "You must learn how to fail intelligently . . . I can take any group of young people and teach them to be inventors if I can get them to throw off the hazard of being afraid to fail". There are . . . different angles of approach to industrial research, which Kettering once described to me: "You can have a Monte Carlo when you put a lot of clever young men into a laboratory and hope for something to turn up. You can build a publicity laboratory in stainless steel, fill it with coloured bottles and apparatus and send for the Press. But then there is the real thing when you make up your mind what is needed and go for it". And that, of course, is what he had done with the self-starter, lead ethyl, and the diesel-electric locomotive.'

I wish that at least the *technical* press were called in more often to see either the Monte Carlo or the Real Thing. I am fed up with the 'publicity laboratory' so deservedly mocked by Kettering.

THE CHARTERED engineering institutions have sometimes struck affronted attitudes toward those who have urged them to do more for the material benefit of the profession in the way that (say) the British Medical Association does for doctors. The plea has usually been that the institutions' charters raise them above the dust of the arena.

Now the Lords have dismissed the I.Mech.E.'s appeal for rating exemption. Their Lordships' reasons appear to be partly that the Institution's charter does not say anything explicit about exclusive devotion to science, and partly that members get substantial professional benefit from their membership.

Since, in the eyes of the law, the chartered engineering institutions are not disinterested champions of science, does this mean that they can now legitimately become interested champions of the engineering profession?

IN ITS LEADING ARTICLE for October 1960 *The Instrument Engineer* has rather taken *Control* to task. We have advocated a live professional body for control engineers without, it seems, explicitly taking note of the S.I.T.'s claims to perform this function. It is a pity that such a view can have been taken of *Control*'s stand. I don't think anybody will dispute the S.I.T.'s pre-eminent right to represent British control engineers—given suitable revision of the Society's name and constitution. As yet, however, it is not a qualifying body, and it appears on the international stage only as one of many (and variously interested) constituents of the B.C.A.C. Our critic writes that it would be very sad if the S.I.T. were to be 'overlooked in a burst of misguided enthusiasm for some other body to be formed which attempted to provide a new professional body of control engineers. This would divide and weaken the profession and set back the clock by many years'. For my part I entirely support this view. I wish and hope that the S.I.T. may evolve into a fully-fledged control engineering institution, but I fervently echo *The Instrument Engineer*'s final cry: 'it would be heartening to see a start'.

A REPORT has reached me, from a usually unimpeachable source, that several automatic reading and sorting machines were recently rejected by the Post Office. They were thrown out with real regret, because they had promised to help considerably with the Christmas rush. Apparently they all came through most of the tests without much trouble, but failed on one. This was to assign routes for a couple of letters addressed respectively to gentlemen in Ari Jaba and Claque de Nancy. Unlike the clever code-crackers of the G.P.O., the computer logic circuits found this problem most unreasonable. The right answers—in case you haven't guessed yet—were Harwich Harbour and Clacton-on-Sea.

Automatics at Carreras

Tobacco feeding system for cigarette manufacture at Basildon

THE AUTOMATIC SYSTEM WHICH Carreras have installed in their cigarette factory at Basildon, Essex, is now understood to have completed its trials successfully. Officially opened by the Duke of Edinburgh in March, the system was applied at first to a section of the plant, but is now being extended to serve all machines.

Designed and built by Hauni of Hamburg, the automatic system links the movement of tobacco from driers, the charging of the cut-tobacco silos, its discharge to a feeding unit, and its supply to the cigarette makers. Manual handling has been replaced by pneumatic handling under push-button control, the tobacco travelling along ducts and conveyors. The system is said to have provided a gain in precision, and saving of time and labour. Charging the silos now takes one-third to one-quarter of the manpower previously required, and feeding the machines about one-fifth the manpower.

Control of silos

Pneumatic conveyors transport the cut tobacco from the processing department to eight 13,000-lb silos Fig. 1), each consisting of four belts holding approximately 3250 lb of tobacco. The operator can charge any silo on pressing the appropriate switch on the control panel of Fig. 2. Light signals on the panel indicate which belt of which silo is receiving tobacco and also report the progress of the filling operation. It is impossible to overfill. If a silo or belt is full and the operator omits to switch to another, filling ceases, and the conveyor reverses automatically and discharges into trolleys. If a conveyor halts through overloading, all conveyors stop, a klaxon sounds, and lights on the panel indicate where the breakdown has occurred. Selector buttons prevent a belt from being both charged and discharged simultaneously, and if a transmitter lamp on the silo fails, all lamps on the instrument panel flicker in warning. A special control permits samples of the tobacco to be taken while it is in transit.

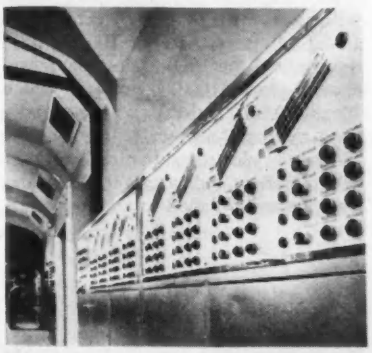
Any two silos can be connected at a time to the funnel of an automatic feeding unit, into which the silo-belts discharge the tobacco. The feeder has four hoppers, each feeding four cigarette-making machines, and either silo can be switched to any hopper. As each of the two silos holds a different blend of tobacco, the operator can feed either blend to any group of cigarette-making machines.

If the feed is blocked or other faults occur, the same kinds of indication and control operate as at the charging end of the system. The feed to any hopper is cut off, or the belt stopped.

Feeding the machines

One machine only, in each group of four, is fed at a time, the selector mechanism switching a supply to each in turn. Without this selectivity, four times the quantity of air would be used—i.e., sixteen machines are being fed for virtually the same cost as four in a more flexible system. There is a corresponding economy in the size of motors, ducts etc.

The tobacco is carried pneumatically along the feeder pipes to an airlock in the hopper of the cigarette-making machine. In the hopper is a photocell which signals to the con-



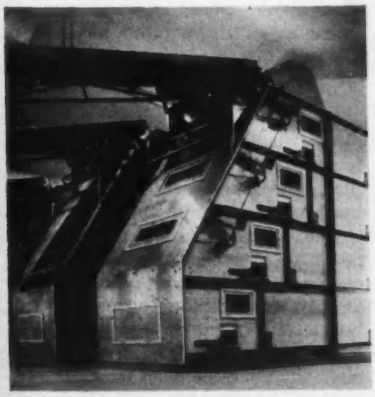
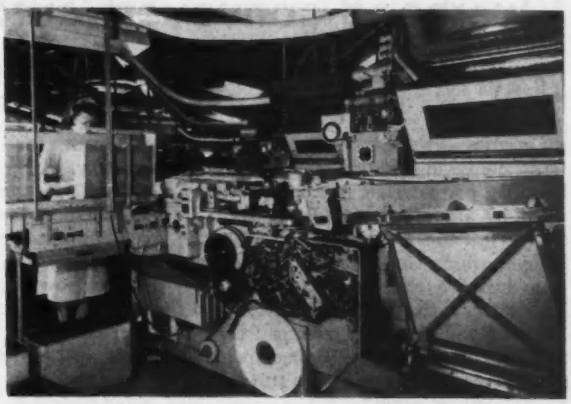


Fig. 1 (left) Each cut-tobacco silo incorporates four 3250-lb capacity belts

Fig. 2 (above) One of the control panels for the automatic feeding system

Fig. 3 (right) A Molins cigarette-making machine at Basildon. The weight per unit length of tobacco rod is obtained by passing it through a beta-particle scanner



trol panel when the level of tobacco falls below a beam of light. If such a signal is received from one machine while another is being fed, a memory device in the control panel stores this information and provides a supply as soon as the first machine is full.

The memory device operates a solenoid, so opening an air damper and sending a blast of air through the pipe. This closes the airlock and operates a pneumatic switch in the automatic feeder, Tobacco then passes from the automatic feeding hopper into the airlock, the supply being regulated by an automatic timer. When the required amount of tobacco has been supplied, the timer halts the feed, and another timer operates to allow air to enter the pipes and clear them of tobacco. The airlock then opens and discharges the tobacco into the hopper of the machine.

Cigarette weight analysis

In order to assess the performance of the cigarette-making machines at Basildon, Carreras have installed a new high-speed electronic weight-analysing equipment by Molins Machine Co. This device is switched from machine to machine in sequence so that all can be checked for proper operation.

Each cigarette-making machine incorporates a scanning unit of the well-known beta-particle absorption type which measures the weight per unit length of the cigarette rod. The resulting weight signal is compared with a reference signal to give an output proportional to the deviation from the desired mean weight. This output is amplified in an electrometer and passed to the central analyser shown in Fig. 4.

The analyser incorporates a 1000-c/s oscillator whose output is fed to the gate circuits of five weight categories—'extra heavy', 'heavy', 'correct', 'light' and 'extra light'. 'Correct' weight is within ± 2% of the desired weight; 'extra heavy' and 'heavy' are outside + 2%; 'light' and 'extra light' are outside − 2%; and 'extra heavy' and 'extra light' are beyond 4% heavy or light, respectively.

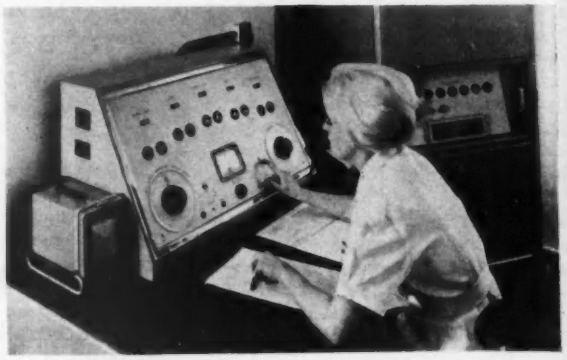


Fig. 4 The central weight analyser can be switched to any of up to 35 machines to give an instant check on the weight specification of the cigarettes produced

The rapidly-varying d.c. weight signal from the high-speed electrometer (this has a time constant corresponding to one cigarette length) is amplified to a high voltage level by a drift-corrected d.c. amplifier. The amplitude and polarity of this voltage determines the counting channel (weight category) which is to receive the pulses from the 1000-c/s oscillator.

Two Dekatron tubes are associated with each weight category, and these reduce the 1000 c/s pulse-speed to 10 pulses/sec for display by electromechanical counters. After a 100-sec analysis period, the 1000-c/s oscillator will have produced 100,000 pulses of which 70% (70,000 pulses) will normally appear in the 'correct' category. The 'correct' electromechanical counter will therefore indicate 700. The analyser is then switched to another cigarette-making machine and the process repeated.

From the figures indicated by the electromechanical counters, a 'standard deviation' may be calculated for every machine. If required, a chart recorder will provide a record of any particular analysis, the shape of the graph being of value to those concerned with maintaining the machines.

An advantage of this system is that the 'correct' counter indicates directly the proportion of cigarettes which meet the desired weight specification, so giving an absolute check on the product. Any increase in over- or under-weight cigarettes is immediately apparent, so enabling corrective action to be taken without delay.

The weight analyser at Basildon is switched manually from one machine to the next, but Molins have now designed a central analyser which is switched automatically, prints-out its results, and incorporates alarm facilities.

According to Carreras, this use of a central weight analyser together with modern cigarette-making machinery, enables them to produce cigarettes of a high standard with the minimum deviation from specification.

CONTROL IN ACTION

Overhead conveyors auto-controlled

Feeding thirty machines with seventy different materials

AN ELECTRONICALLY-CONTROLLED OVERhead conveying system for selective handling of materials has been developed by an Elliott subsidiary, Webb Conveyors and Automation Ltd. This system, which *Control* saw in operation during a recent visit to Elliott's Rochester factory, permits selective handling with standard overhead conveyors; the mechanical attachments usually needed to modify the standard equipment for this duty are unnecessary.

A typical system, now in course of manufacture, involves thirty plastics-extrusion machines, each of which can be supplied with any one of seventy different powders. On long continuous runs, some machines may use the same material for weeks at a time, whilst others will require a different feed every few hours. It is understood that this particular system will handle such feed variations in less than two minutes, under the control of a single operator at a central console.

The thirty extrusion machines are fed with raw material from a Webb overhead chain conveyor, carrying fifty 100-lb capacity, bottom-emptying buckets moving at a speed of 30 ft/min. The conveyor passes under pneumatically operated gates (Fig. 1) which

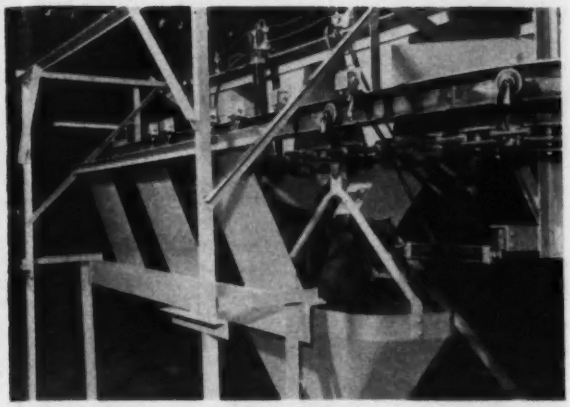


Fig. 1 (left) Filling a moving bucket from a storage bunker. A gate opens on receipt of a combined demand and bucket signal

Fig. 2 (below, left) A signal from the console raises a pneumatically operated ramp on the demanding machine's hopper, so that a travelling bucket is caused to discharge into the hopper

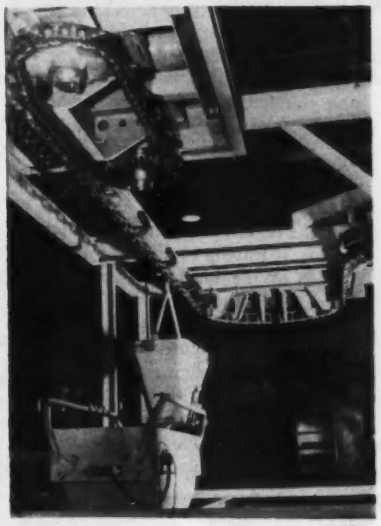
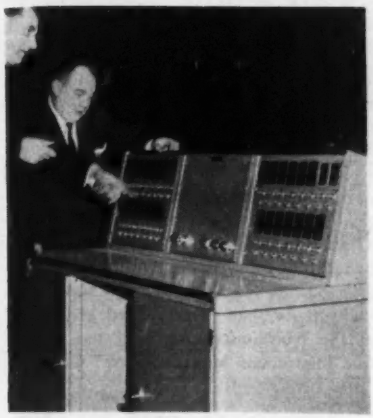


Fig. 3 (below) The central control console of the system provides patchboard programming, bucket counting, and visual indication both of demands for material and of material on the way to machines



control the discharge of materials from the seventy one-ton bunkers, and then continues above the machines in a closed circuit. Each machine has a separate hopper fitted with a minimum-level detector. Pneumatically operated ramps, mounted over the machine hoppers (Fig. 2), are raised automatically to engage those buckets which carry the particular material called for by a machine. The contents are emptied into the hopper, and the bucket completes the circuit of the conveyor before being blown and wiped clean automatically. This installation handles 6 ton/h and *Control* understands that this capacity can be increased threefold.

The system operates as follows: a continuously operating machine consumes material to a preset minimum quantity. This results in a signal being sent to the control console (Fig. 3), where it is held pending the arrival of an empty bucket at the appropriate bunker. As soon as an empty bucket arrives at the bunker, the required material is discharged into it and thus conveyed to the machine.

The operator at the console can change the material feed of any machine during normal working, without affecting any of the other machines. He simply changes a plug from one socket to another on a patchboard, whilst the control system goes on monitoring the supply of material to all thirty machines.

Conveyor control system

The information fed to the control centre consists of impulses from limit switches fitted next to the bunkers and machine hoppers; these signals thus indicate the presence of empty or full buckets at all the loading and discharge points. Material-demand information is supplied from level indicators incorporated in the hoppers of the machines, and panel lamps are used to display it both at the machine and at the control console. There is also visual indication at the control console of material that is *en route* to meet demands by machines.

The signals from the control centre consist of operating potentials applied, at the proper times, to the solenoid-operated pneumatic rams. These rams operate the bunker-discharge gates and bucket-emptying ramps. Other controls include machine close-down switches, supply switches, a program-changing patchboard, and predetermining counters.

Considering Fig. 4, and taking as an example one machine and the bunker from which it is programmed to receive material, the normal sequence of events is apparent. The level of material in the machine's hopper falls below the preset minimum. This initiates a demand signal which is passed to the control console, and, via the patchboard, into a logic circuit. Part of the latter is driven into a request condition, a request which is answered only when an empty bucket signal is also present, the combination causing the particular bunker's gate to open for a predetermined time to let the required amount of material be deposited in the bucket.

A filled bucket is then *en route* to the machine which requires its contents. The conveyor-trolleys actuate a predetermining counter as they pass. This counter has preset upon it the number of trolleys between the machine and its programmed bunker, and when that number has passed, the counter emits a signal which causes the bucket-discharge ramp to be erected over the machine. The ramp falls after the bucket is discharged.

The whole sequence can be considered as a closed-loop system with the hopper-level signal as the error which causes the bucket to be filled and fed back along the conveyor to correct that error.

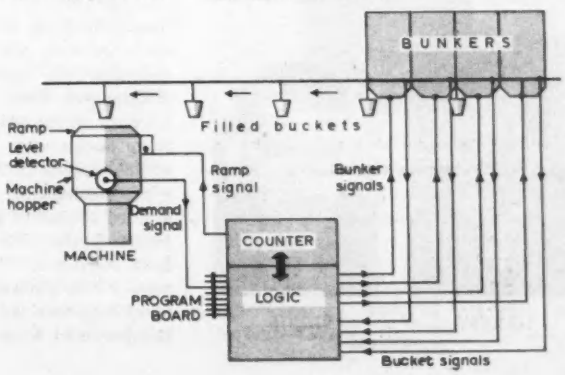


Fig. 4 Schematic diagram showing one machine of the system only. A level detector provides a material - demand signal which causes a bucket to be filled with the demanded material and emptied into the hopper of the demanding machine

PEOPLE IN CONTROL

by Staffman

BRABAZON
president

THORNEYCROFT
minister

The Minister of Aviation, **Peter Thorneycroft,** was the guest of honour at the annual dinner of the radio and electronics industry, held at the Dorchester in London last month, but if any of us there expected revelations from the industry's biggest customer, they were disappointed. Sir **Thomas Spencer,** Chairman of S.T. & C., tried to persuade the minister that taxes on earned income were forcing salaries up too high, but the honoured guest remained inscrutable. The Radio Industry Council's President, Lord **Brabazon,** endorsed Spencer's plea, and we were left hoping that the message would get home. **E. E. Rosen** (Ultra Electric), Chairman of the R.I.C. and member of the Council of the Electronic Engineering Association, assured doubters that there is no difference between an electron in a domestic television receiver and another serving somewhere in industry, and uttered a warning that if one of the twins were killed then the other might die as well.

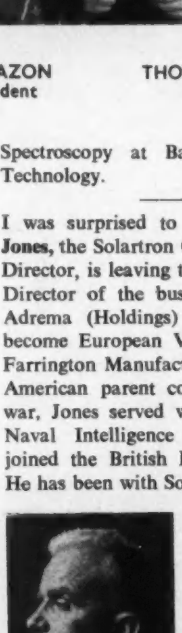
Having acquired a thirteen-acre site near Southend, Ekco Electronics have reorganized individual responsibilities in order to take advantage of the expanded facilities. **P. L. Stride,** formerly Manager of Ekco's Malmesbury Works, becomes Manager of the Aviation Division, handling the design and technical liaison for both ground and airborne equipment. **P. J. Harvey,** formerly Chief Electronics Engineer, becomes Manager of the Nucleonics and Industrial Division, which is responsible for research and development covering nucleonic and physical instrumentation and control. **E. B. Thompson** will, however, continue to handle the commercial activities of both divisions as Sales Manager. Thompson, incidentally, has been elected chairman of the Nucleonics Group of the Scientific Instrument Manufacturers' Association.

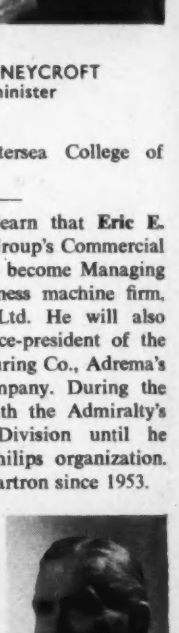
HARVEY STRIDE
reorganized

A. S. D. Barrett, who has been appointed consultant to the Philips company, Research and Control Instruments Ltd, joined the board of directors last month. He was Technical Director of Edwards High Vacuum until the beginning of this year, leaving to set up in private practice as an industrial consultant. Barrett is a Vice-chairman of S.I.R.A., Secretary of the International Organisation for Vacuum Science and Technology, and a founder member of the Company of Scientific Instrument Makers.

The (American) Rosemount Engineering Co.—precision platinum resistance thermometers, etc.—has set up a British subsidiary with **Barry Rogel** as Managing Director. Rogel led Wayne Kerr's microwave design team and, in recent years, made a special study of the measurement of semiconductor parameters with the aim of extending the use of the transformer bridge. He will continue to act as a consultant to Wayne Kerr, along with **A. L. Cullen,** Professor of Electrical Engineering at the University of Sheffield, and **V. S. Griffiths,** Reader in Spectroscopy at Battersea College of Technology.

I was surprised to learn that **Eric E. Jones,** the Solartron Group's Commercial Director, is leaving to become Managing Director of the business machine firm, Adrema (Holdings) Ltd. He will also become European Vice-president of the Farrington Manufacturing Co., Adrema's American parent company. During the war, Jones served with the Admiralty's Naval Intelligence Division until he joined the British Philips organization. He has been with Solartron since 1953.





JONES
moving

MARRIOTT
retiring

I see that **Arnold Lindley** is to succeed Sir **Leslie Gamage** as Chairman of G.E.C. on the latter's retirement at the end of the month. This was to be expected, of course, for Lindley is already Vice-chairman and Managing Director.

However, I can't help wondering how he would have got on with that powerful personality English Electric's Chairman, Lord Nelson of Stafford, if the projected E.E.-G.E.C. merger had gone through. It was thought that Nelson would be Chairman of the combined company. An internationally-known figure in the nuclear energy and engineering world, Lindley joined G.E.C. as an engineering apprentice in 1918 and has served the company ever since.

Another impending G.E.C. retirement is that of **G. A. Marriott,** Managing Director of M-O Valve, who intends giving up the reins next March. He will be succeeded by **J. Bell,** who is at present Deputy Director and Manager of G.E.C. Research Laboratories and a member of the M-O Valve board.

The recent death of Sir **Cecil Weir,** who was Chairman of International Computers and Tabulators Ltd, is a sad loss to the I.C.T. board. I understand that pending the appointment of a Chairman, **H. V. Stammers** is Acting Chairman. He was Deputy Chairman of British Tabulating Machine prior to the merger with Powers-Samas and the formation of I.C.T. last year, and is also Chairman of the jointly-owned G.E.C.-I.C.T. company, Computer Developments Ltd. **Cecil Mead,** another ex-British Tabulating man, who was I.C.T.'s Managing Director, has been appointed Deputy Chairman, and **John Bull** (also a British Tab. man) becomes Managing Director.

My illustration, above, shows a meeting of Directors of the French, Dutch and British Teleflex companies at Basildon recently. They are (left to right): **J. A. De Lijster,** Managing Director of Teleflex N.V. (Holland); **H. G. Burrage,** Director, **J. S. Bentley** and **E. Shetley,** Joint Managing Directors, and **V. H. Robinson,** Director of Teleflex Products Ltd; **M. Thieulin,** Managing Director, and **M. H. Lionel-Dupont,** Vice-President of Teleflex (France). They met to co-ordinate their joint efforts in order to avoid duplication of development.

My interest in the Teleflex organization was further whetted by the news that Teleflex Products is being visited by the Chief Engineers of the Danish, Norwegian and Swedish companies representing Teleflex interests in Scandinavia. The international flavour of these gatherings made me wonder who controlled whom, but I am assured that all —including Teleflex Inc., U.S.A.—are 'associates', and that the British firm is the parent company.

AUTHORS IN CONTROL

R. N. Aldrich-Smith (*Controlling the production of nylon yarn,* page 92) specialized in instrument design under the late Professor A. F. C. Pollard, having graduated in physics and mathematics at Imperial College in 1939. After a graduate apprenticeship with the Cambridge Instrument Company, he spent most of the war years in the Armament Research Department of the Ministry of Supply on physical metallurgy and the design of automatic inspection equipment for armament components. Subsequently he joined the team responsible for the design and development of the Mk IX automatic aircraft pilot at S. Smith & Sons, and became Deputy Principal of their Cheltenham Technical School. At British Nylon Spinners he has for the past eleven years been senior engineer responsible for instrumentation and control engineering throughout the company.

A. G. Ivakhnenko (*New methods of control-system investigation,* page 96) is a member of the Institute of Electrotechnics, Kiev, which comes under the Department of Technical Sciences of the Academy of Sciences of the Ukraine, U.S.S.R. Professor Ivakhnenko directed a laboratory devoted to research on automatic control until quite recently, the laboratory doing basic work for the Institute of Automation in Kiev as well as for the Institute of Electrotechnics. He is Professor in the Department of Electrical Engineering in the Polytechnical Institute of Kiev, and is Deputy Editor of *Automatika,* a learned journal devoted to instrumentation and automatic control.

Last spring he visited this country to give a series of lectures under the auspices of the Royal Society. (See Williams, G. M. E., 'Back and forward', *Control,*

Aldrich-Smith

Ivakhnenko

May 1960.) Those who met him speak of his great ability and most pleasing personality. (Photo by courtesy of Ekco Electronics.)

John Tindale (*Control mechanisms for nuclear reactors,* page 100). See page 126, November 1960.

A. J. Morton (*Boiler feed discharge systems under changing load,* page 106). See page 126, November 1960).

Denis Taylor (*Improvements in radioactivity monitoring,* page 109) was a lecturer in electrical engineering at Hull and London before joining the Air Ministry and becoming a member of the team which developed radar. During the latter part of the war he was Superintendent Scientist at the Telecommunications Research Establishment and, later still, was in the Far East for a year, assisting the R.A.F. and the Fleet Air Arm with their radio and radar problems. After the war be became one of the founder members of the Atomic Energy Research Establishment at Harwell. He was appointed Head of the Electronics Division, a position he retained for eleven years, until he joined the Plessey Group of Companies to take charge of their nuclear program.

Dr Taylor is the author of many scientific papers and books on radar, control systems, nuclear measuring instruments and nuclear reactor instrumentation. He has been Chairman of the Measurement and Control Section of the Institution of Electrical Engineers, and has represented

Taylor

this country at many international conferences. He is a consultant to both *Control* and its sister journal *Nuclear Power.*

P. F. Blackman (*Pole-zero approach to system analysis,* page 112). See page 126, November 1960.

NEWS ROUND-UP

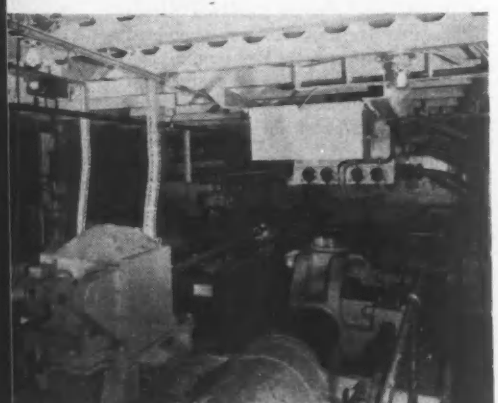
from the world of control

SHIPPING

Controlling 'Oriana'

The new P. & O./Orient liner *Oriana*, which sailed on her maiden voyage on December 3, has a number of equipments aboard of control interest, apart from the Sperry-Brown Bros. gyro-hydraulic steering control, illustrated. The ship has been fitted with the Denny-Brown stabilizer system, and this is controlled by a Muirhead gyro unit. The latter is sensitive to roll angle, roll velocity, roll acceleration, natural list and fin position, and is capable of reducing a ship's roll from $\pm 20°$ to about $\pm 3°$.

Muirhead have also supplied two 'integrating power meter, shaft-speed and hp-indicating' equipments—one for each propeller shaft. The main purpose is to determine the total work—in horsepower-hours transmitted by the propeller shafts—and to display the result on counters. Read-outs also give the mean shaft speed and mean hp over intervals of 36 s or 6 min. The equipment can be used to measure, and keep a check on, the friction of the propeller shafting and glands, for example, or to compare the total work expended during successive voyages.



Cybernetics in 'Oriana' The s.s. 'Oriana' has Sperry-Brown Bros. gyro-hydraulic steering control which takes its heading reference from a Sperry mk XIV gyro compass. The latter provides heading information for a number of repeaters, Decca true motion radars and Marconi Lodestar automatic direction finder. The gyro-hydraulic steering control works in association with the standard Sperry 'after power unit' (seen in the left foreground of this photograph of 'Oriana's' steering flat) and the Brown Bros. telemotor receiver with which it is linked. These latter units provide two independent methods of controlling Brown Bros. electro-hydraulic steering gear which occupies the remainder of the picture

Automatic turning gear

In order to turn the rotors of the ship's turbines at a very low speed, thus preventing shaft distortion that could occur if the rotors are allowed to cool or warm up in a stationary condition, automatic turning gear has been provided by A.E.I. This can be done by opening the turbine stop valves partially, so as to produce some rotation of the rotor. This method, however, is difficult to control, and may necessitate unwanted rotation of the propellers, and consequent interference with the manœuvring of the ship. The A.E.I. gear permits very slow operation, say 1 rev/10 min. Controlled hydraulically from the main manœuvring platform, the mechanism consists of an electric motor connected to one of the turbine pinion shafts through a combined spur and worm reduction gear and a male and female toothed clutch. Clutch engagement is ensured by a relay system, and interlocks ensure that the gear cannot be engaged unless the turbines are at rest, and that steam cannot be admitted to the turbines unless the turning gear is disengaged.

Steam controls

Fisher Governor's Wizard pressure controller is used in the engine room in conjunction with Fisher diaphragm control valves, to reduce steam pressure for various services throughout the vessel. The controllers are fitted with stainless steel Bourdon-tube measuring elements, and give an air output signal of 3–15 lbf/in²g to operate the control valves. These valves are said to withstand the erosive effect of high velocity steam, and the stainless steel inner valves are covered with sprayed-on Stellite. Mains steam at 750 lbf/in²g is reduced in some instances to 300 lbf/in²g and in other cases to 30 lbf/in²g, and it is claimed that the controller will maintain the required pressure regardless of changes in flow demanded or upstream pressure. In all, twelve such valves have been provided, in sizes ranging from 1 in to 3 in.

A variation of this type of control is used for providing low pressure steam for the turbine gland sealing, and two specially designed 2½-in three-way valves are used for this service, again controlled by a Fisher Wizard, this time maintaining a reduced pressure of 3 lbf/in²g.

– ANALOGUE COMPUTATION –

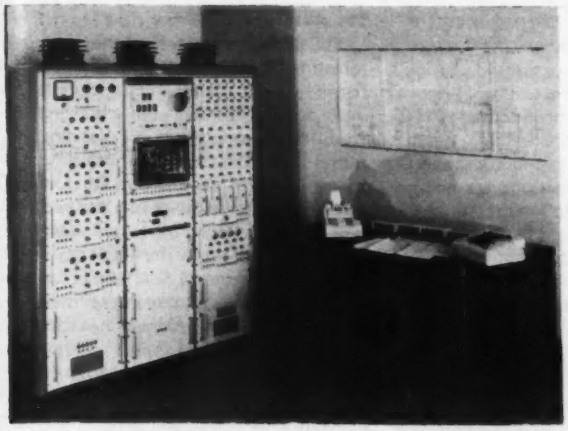
Little on-line at Brussels

The recent Brussels conference on Analogue Computation Applied to the Study of Chemical Processes was expected to include a session on the use of on-line analogue computers for process control. In fact, of the 21 papers delivered at the three-day seminar, only two or three dealt with on-line computation problems, and even these were highly theoretical.

T. B. Jawor (Evershed & Vignoles), for example, discussed a method by which errors in the variables derived by analogue control computers could be estimated—thereby giving a means of comparing the accuracies of alternative on-line computing systems. D. J. Wilde (University of Texas) was concerned with the computer control of 'over-determined' systems—that is, systems with more critical variables than directly adjustable variables. Computer control of such systems could give a reduction in both capital and operating expenses by avoiding the artificial addition of adjustable variables.

Most of the papers dealt with analogue computer studies of chemical processes or of control systems for chemical plant. J. G. Thomason (Imperial Chemical Industries) described analogue simulation studies on boiler control systems in which approximately thirty equations were set up from data obtained from measurements on full-scale boilers and from theoretical analyses. The purpose was to optimize existing control systems and assess the performance of proposed systems.

Simulation studies of control systems were also described by J. P. Bromley



Radic—Redifon analogue-digital computer—is to be used by the Admiralty Experimental Works, Haslar, as a simulator for designing naval control equipment and instrumentation

and C. Storey (C.J.B.). One system was for the control of product quality from a distillation column. For this, transfer functions representing the column had to be obtained by digital computing techniques before the analogue simulation could be performed.

A new method for simulating closed-loop control systems by analogue computer was put forward in a paper by J. Rissanen (I.B.M. Nordiska Laboratorier). This was based on a theorem of the generalized linear feedback principle formulated by the author. The feedback signal is taken not only from the system output, but from all the variables in the controlled plant. There are consequently a number of unknown parameters in the closed-loop system which are determined by the simulation procedure.

Another novel technique, described by S. Shapiro (I.B.M.) and co-authors, was the use of combined analogue-digital computing equipment for simulating chemical processes. The object was to avoid the long computing time normally required with a digital computer, or the excessive amount of equipment needed with an analogue machine when simulating large systems. Two standard commercial machines were inter-connected by analogue-to-digital and digital-to-analogue converters for the purpose of simulating a catalytic fixed-bed reactor. Output values of the various stages of the plant were stored by the digital computer and then used as input values for subsequent stages.

About 300 delegates attended the conference, which was organized by the Institut Belge de Régulation et d'Automatisme and held in the Palais des Congrès. The full proceedings will be published next July by the Presses Académiques Européennes, 98 Chaussée de Charleroi, Brussels.

Radic and oil

Radic, the Redifon analogue-digital computing system, which is an analogue computer having digital data storage and is, therefore, claimed to enable certain calculations to be made with equipment which is both simpler and cheaper than conventional computers, was also discussed at the Brussels conference—see above. J. I. Archibald presented *Analogue-digital computing methods*, and A. W. O. Firth, *The use of an analogue computer for the solution of linear and non-linear programming problems*.

Radic has now started work on calculations for the design of super-fractionating distillation columns for the refineries of a British oil company. These calculations are mainly concerned with heat transfer and mass and heat balance problems. There are about a hundred trays in each distillation column, and for each tray it is necessary to solve a second-order differential equation in six variables. As Radic's digital storage unit is arranged to store the initial and end values for each tray in the distillation column, the whole set of calculations can be performed with a relatively small number of operational amplifiers. The calculations take about 1 s per tray to perform, or about 2 min for the whole distillation column.

Another type of calculation for which the Radic is being prepared, is concerned with minimizing the cost of transporting crude oil by sea-going tankers. This type of problem comes under the heading of non-linear programming, and the aim is to find the best possible deployment of a complex network of oil transport facilities in order to arrive at the lowest possible cost.

— FODDER —

Dispensing at Associated Feed

The method of dispensing vegetable and animal oils at Associated Feed Manufacturers' new £2m Belfast factory, is based on rotary piston meters by Parkinson Cowan Measurement. These are fitted with presetable controllers operating solenoid valves, and all indications and controls are grouped on the central console, illustrated.

Four different oils can be fed into sixteen mixing vessels in any combination. The operator presets on the console the amount of oil to be dispensed, and rotates a selector switch to register the same amount. This selector switch controls four proportioning solenoid valves, each adjusted for varying rates of flow so that the time taken to dispense oil is the same, no matter what the quantity. He then selects the mixer into which the batch is to be dispensed, and presses the 'start' button.

Other controls feed meal into the mixer. When the level of the meal reaches a depth probe, the solenoid valve for the appropriate oil or oils is opened, and dispensing proceeds until the preset amount has been fed in. The valve then closes, and the batch

Control console by Parkinson Cowan Measurement for the automatic dispensing of oils at Associated Feed Manufacturers, Belfast

quantity controller is reset to the same quantity ready for the next batch.

Signal lights on the mimic diagram indicate the oil selected, and the mixer into which it will be dispensed. Other lamps at the top of the control panel indicate which of the four proportioning valves are in operation.

— MOTOR CARS —

Bluebird's Didas recovered

The Armstrong-Whitworth Didas telemetry transmitter, which was recovered from Donald Campbell's Bluebird after the crash during the world speed record attempt in September, is badly battered and a write-off owing to its smothering with anti-fire foam. However, A.W.A. have tested the transmitter and claim that the fact that it survived a 360 mile/h crash illustrates the high state of reliability now available from electronic equipment. Didas

—dynamic instrumentation data automobile system—monitored the ill-fated Bluebird's last run, checking the performance of the suspension, steering,

Bluebird's Didas after the crash

engine and gear-box. An A.W.A. engineer, Alan Potton, was watching the gear-box tachometer meter, which was indicating 360 mile/h, when all the needles swung back to zero, and he heard that the car had crashed.

—— DATA PROCESSING ——

E.P.A. Mission to U.S.

A European Productivity Agency mission of 25 members from ten countries visited the U.S.A. from April–June 1960, and their report (*Integrated Data Processing and Computers*) is now — or will be shortly — available from H.M.S.O. The President of the mission was Brian A. Maynard (Cooper Bros & Co.) and the other British members were John A. Goldsmith (Robson, Morrow & Co.), Jack G. Grover (Courtaulds Ltd) and Michael A. Wright (N.R.D.C.). During the eight-week tour, members of the mission visited some fifty industrial and commercial users, thirty government organizations, thirteen universities and educational establishments, five computer service centres, and the principal manufacturers of equipment.

The report gives the impression that, on the whole, the members were greatly impressed, although certain reservations are hinted at. In the ten years since computers were first used for business data processing in the U.S., considerable progress has been made. There are more and larger computers than in Europe, and more experience of business computation. The mission expect further progress to be made because of the large sums being expended on development by both manufacturers and users.

Outstanding attempts are being made by the larger corporations to realize extensive schemes for i.d.p. with computers. For example, order processing, credit processing, inventories and job costs, production scheduling, inventory processing, sales forecasting and financial planning, and general accounting functions are being linked to form a single integrated flow from customer's order to costing and accounting after production. In some cases computers are taking over routine decisions, and consequently decision-making is more rapid and reliable.

The mission appear to be disappointed with the rate at which the possibilities of i.d.p. are being exploited. Many U.S. undertakings are unwilling to pioneer, or do not appreciate the possibilities. On the other hand, several organizations did not expect their installations to pay off for seven or more years.

Having said this, the report about-faces and (although admitting that prestige may have had a lot to do with the initial decision) refers to American managements' greater readiness than their European counterparts to install a computer. As U.S. wages and salaries are double those in Europe, development costs should be lower here. However, the wages aspect also affects the justification for a computer, so growth will be more rapid in the U.S.A. Some suggest, however, that because it is more difficult to justify a computer in Europe, there may be more attention paid to initial planning, and hence some of the better systems could be situated in Europe.

Little saving in staff

The mission reports that the staff savings expected to result from the installation of a computer have not often been achieved. This is thought to be due to underestimating the number of small jobs remaining after a computer has been installed, to the existence of policies of continued employment and, where part only of several employees' times is saved, to the difficulties entailed in reorganizing to make use of that saving.

A particular point is made of the role of the U.S. Government, which has 350 computers either in use or on order.

The report refers to the hundredfold increase in computer speed during the past ten years, and says that machines a hundred times faster are under development. Better utilization is obtained by 'time-sharing' and the use of international computer languages (Algol for scientific work and Cobol — common business orientated language—for business work) is appreciated.

The mission's conclusions

The report makes a number of interesting points: faster and better information for management is available with i.d.p.; integration cuts across traditional boundaries, so leading to more centralization; clerical savings form the main justification for a computer if large amounts of data are involved; operations research was impressive; although the high salaries demanded in the U.S. make it easier to justify i.d.p., management there is also more ready to pioneer new fields; firm management support is important, and poor initial planning stems from a lack of appreciation of the problem by management, together with over-enthusiasm on the part of the installation team, and also because the difficulty of selecting a computer leads to concentration on that, rather than on planning; installation delays may stem from the use of unsuitable (inflexible) staff, especially if they would otherwise be redundant; it is important to eliminate errors in the files of basic data to be taken over by a machine; the U.S. Government is a large user and so cannot avoid responsibility for encouraging development; integration between the d.p. procedures of different organizations gives great savings; education is important, manufacturers often give or lend machines to universities, and 'business games' are educational.

Members of the mission felt that a central source of information on i.d.p. should be set up in Europe.

Woolwich Poly's Zebra

The Stantec Zebra digital computer at the Woolwich Polytechnic was formally brought into service on November 22 at the opening of the Computer Service Centre by Sir Thomas Spencer, Chairman of S.T. & C., and Governor of Woolwich Polytechnic.

The Computer Centre, which is established in the Mathematics Department of the Polytechnic, will be used to provide a service for student training, and as a research tool.

Users in industry and commerce have been invited by the Centre to discuss their problems with the computer staff and to use time on the computer, for which a 'moderate fee' will be charged. The Mathematics Department is prepared to arrange courses on programming methods.

The machine will also be used for training students in the use of digital computers. Every student of the Polytechnic who is studying for a B.Sc. degree in mathematics, physics, chemistry, engineering or economics, and every student studying for a Diploma in Technology or a Higher National

Certificate with endorsements, is to have an opportunity to write programs for and to operate the computer.

EDUCATION

Diversification at Cranfield

During a recent visit to the College of Aeronautics, Cranfield, *Control* gained the impression that the College's emphasis on aircraft and missiles is lessening. The trend appears to be not so much away from aircraft engineering, as toward advanced engineering at large. Furthermore, the Electrical Engineering Department at Cranfield is so deeply immersed in control engineering—including pneumatics and hydraulics—that one wonders where it will end. *Control* suspects that much as the staff of the Department appreciates the importance of the subject, the students are setting a yet faster pace. 'We have to try to steer them away from control, in order to get a proper balance' said one lecturer. And when asked why this was so, he replied, 'Well, it's a glamour subject, a glamour fostered by such journals as yours'.

That's as may be, but there is no doubt that the College itself—and the Department of Electrical Engineering in particular—is doing an enormous amount to put across the idea of the highly-qualified control engineer—the real systems man—as a member of his own discipline, and not as primarily an electrical or other engineer with leanings towards instrumentation and an interest in pipes and valves.

In a rapid and somewhat haphazard tour, *Control* found a great deal of interest. Data handling is being installed to handle the enormous output of information from the wind tunnels, and the 8 ft by 6 ft tunnel is being fitted with automatic control of blade pitch in order that the air flow can be controlled without varying the speed of the driving motor. However, some difficulty is being experienced here. In the Design Department, a digital recorder by Blackburn Electronics is used to obtain data when strain-gauging structures.

Much of Cranfield's increasing interest in data processing stems from the fact that a Ferranti Pegasus is now fully operational in the Mathematics Department. This is a most impressive layout, possibly one of the best in the country.

A great deal of interesting work is being done in the Department of Economics and Production. This includes a large and well-equipped machine-tool laboratory, clean and brightly lit, where work to high accuracies is carried out. The Department, which is getting a Hayes contour miller with Ferranti numerical control, is interested in optimizing the economics of machining by numerical control. Ergonomics is another important interest.

The Department of Electrical Engineering is, of course, full of control equipment. They have recently put a large control bay for secondary electrical supplies—any supply in any laboratory—into operation. This was designed and built at Cranfield—'to show the students that we can do down-to-earth engineering'. The control systems laboratory shows every healthy sign, as do the data handling and measurements laboratories.

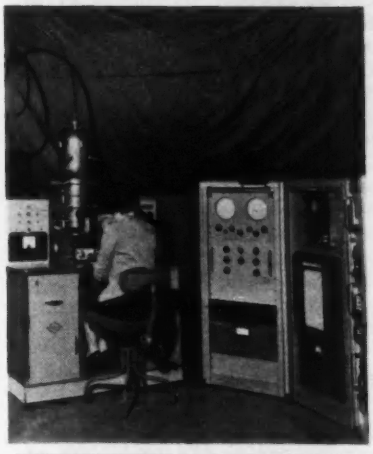
They are now doing some interesting work with a full flight simulator, which was 'acquired' in very poor condition from R.A.E. Basically a Canberra simulator, it has been built up more or less from scratch, and will be used for a variety of teaching and other purposes—i.e. ergonomics, and flight instrumentation and control. Similar work is done with a Link trainer.

See also 'Control at Cranfield', *Control*, May 1960.

Departments renamed

Since the above was written, *Control's* supposition that changes were about to occur at the College of Aeronautics has been confirmed, 'Aircraft' being dropped from the titles of three of the College's departments, and—more significant still—control being officially recognized. The erstwhile Department of Aircraft Electrical Engineering becomes the Department of Electrical and Control Engineering, and includes advanced courses on industrial control engineering and flight control. The Department of Aircraft Economics and Production is renamed the Department of Production and Industrial Administration, and covers economics and production, precision engineering, production technology, operational research, and ergonomics. The Department of Aircraft Materials becomes the Department of Materials, and offers advanced courses on the physics and mechanics of structural materials, and welding technology.

To Assam by way of Roumania. This 64-ft long control panel by Elliott-Automation has been shipped to India for the oil refinery being supplied for Assam by the Roumanian State Trading Agency, Technoimport. E.-A. are supplying the complete instrumentation and control equipment for the refinery



Cambridge microanalysers for U.S. Three Cambridge scanning electron-probe X-ray microanalysers are on their way to U.S. purchasers. One was delivered to the Illinois Institute of Technology, Chicago, last month and the other two —United States Steel Corp., and Crucible Steel Co. of America—are following at intervals of two to three weeks. A fourth instrument is also on order for a U.S. user. X-ray microanalysis consists of focusing a 50 kV electron beam on to a region of the specimen surface approximately 1μm in diameter and rather less in depth, and analysing spectroscopically the X-rays from the specimen. The Cambridge instrument can be used for scanning the specimen's surface over an area up to 0·5 mm by 0·5 mm, as well as for static probe point-by-point quantitative microanalyses

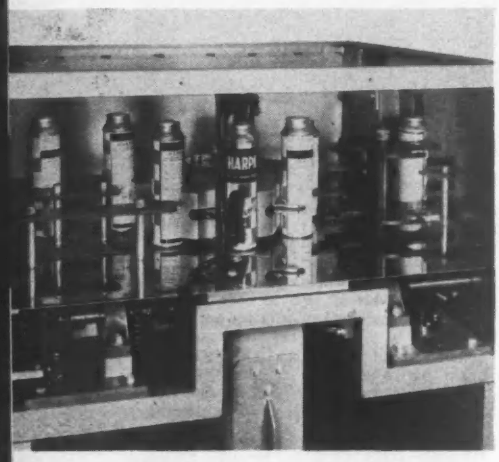
PRODUCTION

Check-weighing Harpic

Elliott-Automa high-speed check weighers have been in operation on the Harpic and Steradent production lines of Reckitt & Sons, Hull, for some time. According to the Industrial Weighing Division of Elliott Brothers, a typical installation can check-weigh at speeds up to 200 cans a minute, and the weighing system, which has passed Board of Trades tests, can

maintain an accuracy of $\pm \frac{1}{2}\%$ of the set level. The speed of the system is largely dependent upon the ratio of the diameter to the height of the cans. The lower the aspect ratio, the faster and more accurately the tins can be handled and weighed.

Cans are delivered to the machine on a p.v.c. cotton-faced belt via a starwheel in-feed. They pass on to an eight-station turrent, designed to reduce the inertia effect encountered at high rotational speeds. A turret-arm clamps each can until it reaches the weigh station where it is lowered on to the weigh-head by a grid which allows the can to stand freely during weighing. The grid then lifts the can off the weigh-head and returns it to the turret.



The in-feed turret, weigh-head and twin output belts can be seen in this close-up of an Elliott check-weigher at Reckitt & Sons, Hull

Underweight cans are released at a 'reject' station under the control of information transmitted to the turret by the weigher. Cans of the correct weight go to an 'accept' station and are released automatically. Parallel belts carry the cans away from the machine, the 'accept' belt being in line with the in-feed belt in order to maintain continuity of the process line.

The handling system is cam-controlled and its mechanism is self-contained and independent of the weighing system. The machine does not require an attendant, and drive cut-out devices operate, together with alarms, if a jam occurs as a result of distorted or bent cans.

TELEPHONES

I.E.E. conference

The recent (November 22–23) I.E.E. conference on electronic telephone exchanges, was an event of great importance to those concerned with telecommunications, for it drew engineers from all over the world. Thirty-eight papers and contributions were presented by members of the Post Office, all the major British telephone manufacturers, and certain foreign firms and organizations. Papers were presented by authors from P.O. Research, P.O. Engineering, Stromberg Carlson (U.S.A.), British Telecommunications Research, G.E.C. Research, G.E.C. Telephone Works, Bell Telephone (Belgium), Bell Telephone (U.S.A.), Standard Telephones and Cables, Ericsson Telephones, L. M. Ericsson (Sweden), A.E.I. (Woolwich), Automatic Telephone & Electric, Pye Telecommunications, the University of Tokyo, Nippon Telegraph & Telephone (Japan), Siemens and Halske (Germany) and Philips (Holland).

The conference was divided into six sessions, two on time-division-multiplex exchanges, one (fourteen papers) on time-division-multiplex exchanges with particular reference to the Post Office's Highgate Wood exchange, two on space-division systems, and a general session.

The present position

It may be recalled that the Post Office is already using electronic equipment to register and control the setting up of subscribers calls. The first electronic director went into service at Richmond exchange in 1952, and still gives reliable service. G.R.A.C.E., the subscriber trunk dialling equipment at Bristol which was opened by the Queen in December 1958, uses electronic equipment. A magnetic drum has also been used as a director at Lee Green exchange in London.

In London and other cities equipped with 'director' exchanges which are to have subscriber trunk dialling next year, G.R.A.C.E. will use a magnetic drum to control routing and charging. A model electronic exchange has been installed at the Post Office Research Station, Dollis Hill, and when experiments with this model are complete—probably in the next year or so—equipment for about 1000 lines will be installed as a public exchange at Highgate Wood, in North London.

BUSINESS

E.E.-G.E.C. merger off

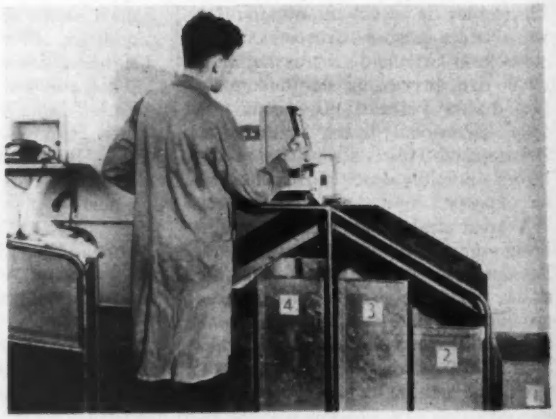
The discussions between English Electric and General Electric, which were intended to bring about a merger between them (see these columns, October 1960) have been called off. The reasons for this have not been divulged, but the financial press takes the view that the two companies could not agree on the percentages of the shareholding in the combined company, which they should each receive. Apparently, English Electric shareholders' earnings are such that they felt entitled to a 60% holding in the new company; on the other hand, G.E.C.'s assets are such that they are supposed to have considered a fifty-fifty division to be more fair.

Whatever the reason, it would have been a terribly complicated merger, and it could be that its cancellation will not displease the companies' employees. However, we probably haven't heard the last of the matter.

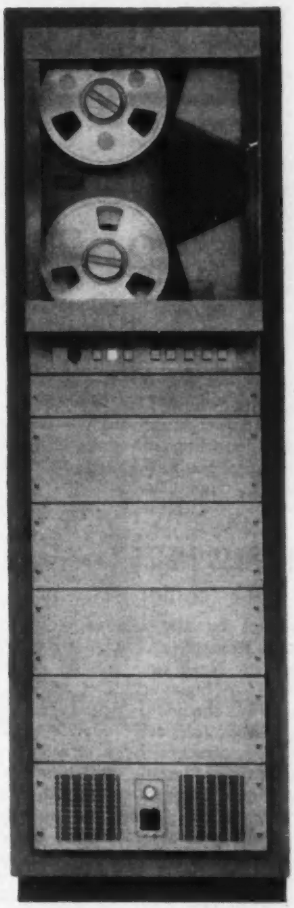
TEXTILES

Automatic cop grading

Now being marketed by Lancashire Dynamo Electronic Products is a machine for the automatic grading of cops, or yarn packages. Developed by the Wool Industries Research Association, it will sort cops into six weight grades. An Avery Shadoweight scale, in which displacement of the weigh beam is sensed photo-electrically, provides weight signals controlling a selector mechanism which diverts the cops into the appropriate bins. The numbers handled are indicated visually. The grading machine rejects excessively light or heavy cops.



Cop grader polices yarn package weight. The prototype W.I.R.A. cop grading machine



The AMPEX FR-400 is a versatile, dual-speed digital magnetic tape handler for use with computers and auxiliary digital equipment with transfer rates up to 22,500 characters per second. It is a reliable, efficient input source for operating printers, plotters, computer language translators and paper tape and card punching equipment. It is used to record the output of punched cards and paper tape reading equipment, and analogue-to-digital converters. The standard speeds of the FR-400 are 75 and 37½, or 60 and 30 inches per second. Other ranges can be supplied on special order. Fast start/stop times of under 5 milliseconds provide maximum tape utilization. Compact, all-transistorized etched circuit electronic assemblies assure reliable performance and low power consumption. The FR-400 is available in models for ½, ¾ or 1-inch tape, providing from 7 to 16 data channels. Pushbutton controls, straight-line threading, power interlocks and end-of-tape sensing simplify operation. Complete technical performance specifications and information on your specific applications are available from Ampex Great Britain Limited, Arkwright Road, Reading, Berks., England. AMPEX

New for Control

A monthly review of system components and instruments

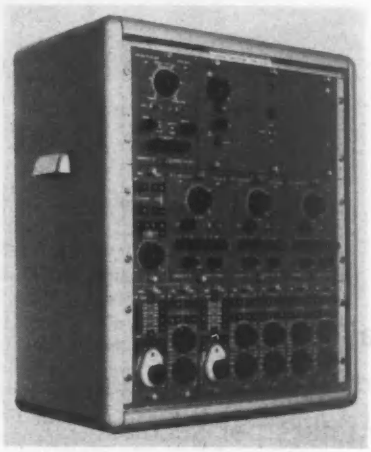
For further information, circle the appropriate number on the reply card facing page 198

SYSTEM SIMULATOR

inexpensive, compact

Designed particularly for experimental work on analogue and allied techniques, the Feedback SS110 can simulate a variety of systems described by linear second-order differential equations.

The equipment consists of six amplifiers, eight interconnecting units of three basic types to provide transfer functions,



For experimental work

a square-wave generator for repetitive transient-response tests at mains frequency, and a stabilized d.c. power supply.

Circle **No 506** on reply card

VIBRATION CALIBRATOR

acceleration accuracy ± 10%

Consisting of a transistorized electromechanical oscillator and a battery-operated cylindrical shaker, this instrument provides a standard acceleration of 1 *g* r.m.s. at 100 c/s. Acceleration output appears at two pillbox-shaped 50-gram disks mounted on an internal cylinder extending through the instrument and projecting at the sides. The pick-up to be calibrated is attached to, or in place of, one of these disks. Acceleration accuracy is ± 10%; frequency accuracy is ± 1%.

To subject a pick-up to an acceleration of 1 *g* at 100 c/s, the level-control is adjusted until the panel meter, calibrated in grams, indicates the mass of the pick-up. Power is supplied by four mercury-cells, whose life is 100 hours, and the total weight of the instrument (including carrying case) is 1·5 kg. Made by General Radio (U.S.A.), obtainable in the U.K. from Claude Lyons.

Circle **No 507** on reply card

THICKNESS METER

coulometric principle

Designed by the British Non-Ferrous Metals Research Association, a plating meter by Nash and Thompson is designed for high accuracy rather than speed. In the coulometric method, a small, accurately determined area of the surface is attacked by a stripping solution, with or without agitation. At the same time a current is passed through the cell and the plating, and an integrating circuit provides a reading based on the current density and the time taken to strip the plating. Readings between 0·000004 in and 0·0015 in may be made to an accuracy of ± 5% for the following combinations: nickel on steel, brass, copper, or aluminium; copper on steel or zinc; cadmium on steel; chromium on nickel; and zinc on steel.

Circle **No 508** on reply card

CHOPPER RELAY

very low noise-level

The type-D relay is designed for use where noise must be kept to a minimum; under certain conditions signals as low as 10 μV may be chopped. Contacts are gold alloy, and may be single-pole, double-throw, or double-pole, double-throw; loading may be 10 mA at 1 V, or 1 mA at 10 V.

Standard frequency of the relay is 40–60 c/s, but it will operate up to 100 c/s. Standard coil has a resistance of 500 Ω, and is rated for 6·3 V with a drive-power of approximately 16 mVA. Made by Ericsson.

Circle **No 509** on reply card

SURVEY PANEL

digital indication

To facilitate central supervision and cost control, complete installations are available from Radiatron for the digital indication and printing of plant-consumption measurements. These include integrated flow of liquids and gases, and electrical power. The system is designed for automatic plant-supervision where complicated electronic computer systems are not justified.

The equipment operates from instruments producing an electrical pulse or switch closure for each unit consumed, and is based on the Kienzle transistorized digital printer, using counting stores which retain their information in the event of mains failure. Pulses from the measuring instruments are integrated in the stores, each channel representing a plant department or a type of fuel. The accumulated pulses in each channel are displayed continuously on electro-mechanical registers or in-line indicators. A programming unit initiates printing at preset times in some or all the channels, and includes switches for each channel to select either totalizing or resetting to zero after printing.

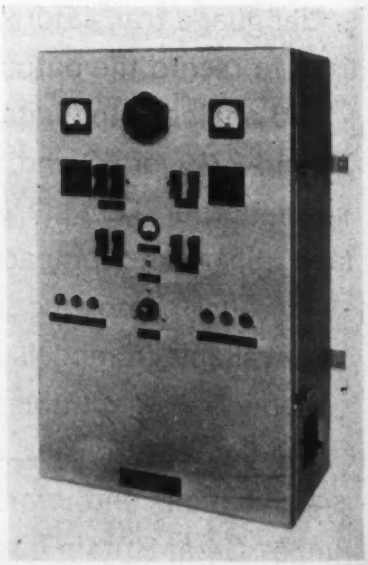
Circle **No 510** on reply card

GENERATOR CONTROL

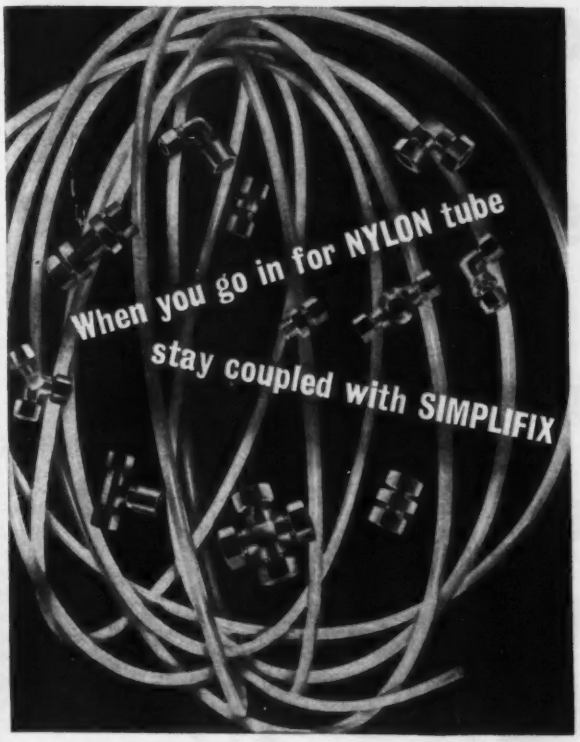
emergency supply

A 'mains failure' control panel is designed to work with a diesel generator to provide continuity of supply for essential services. It provides a starting signal to the diesel engine after sensing a loss or partial reduction of mains voltage. The mains supply is automatically iso-

Ensures essential supplies



Circle **No 89** on reply card for further details



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Simplifix compression couplings for nylon tube. Simplifix olives and securing nuts for nylon tube are available for standard coupling bodies in O.D. tube sizes of $\frac{3}{16}$", $\frac{1}{4}$", $\frac{5}{16}$", $\frac{3}{8}$" and $\frac{1}{2}$". Complete couplings for nylon tube are also available in same range of sizes. Nylon tube can also be supplied by Simplifix in a wide range of colours and sizes.

Technical literature sent on request.
Technical representatives available on call.

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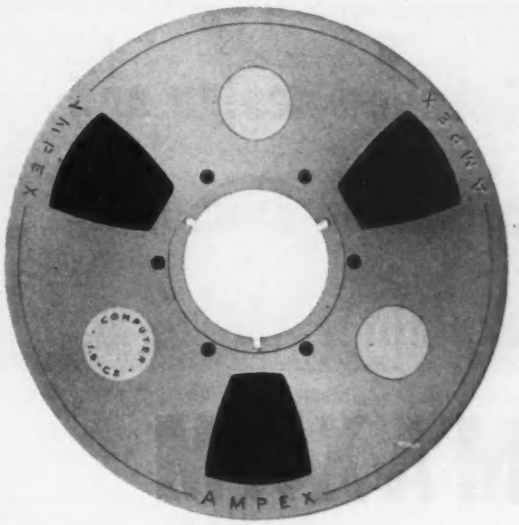
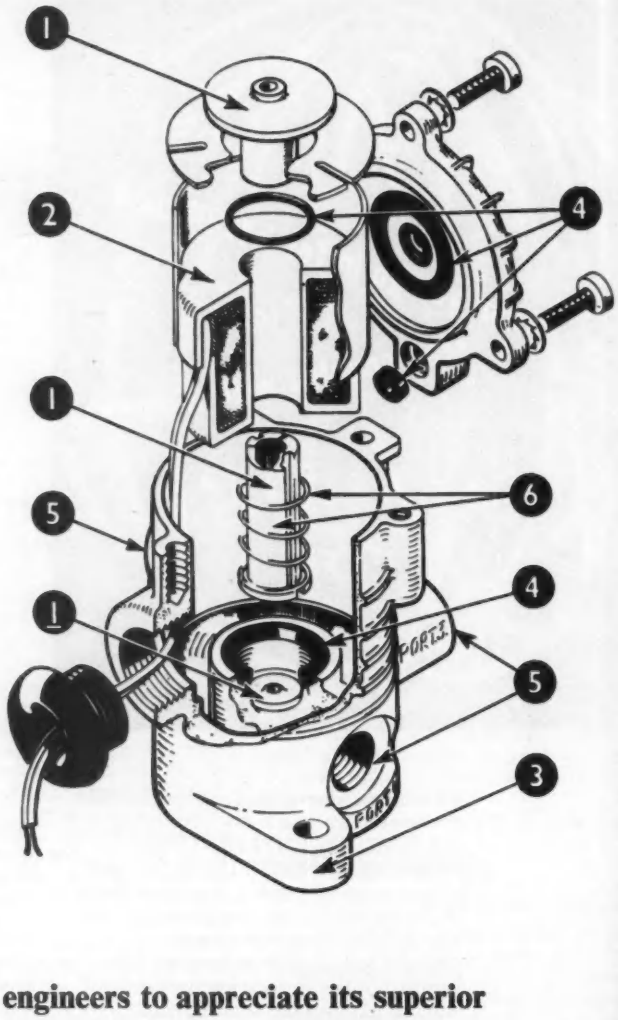


AMPEX Computer tapes

are premium quality magnetic tapes designed for digital recording and computer applications. They offer both long life and optimum performance, and are 100% checked for reliability and freedom from drop-out. Magnetic surfaces are exceptionally smooth and hard, providing cleaner operation with less oxide shed, offering reduced maintenance and greater reliability. These tapes are available in a number of configurations to meet the operating requirements of the various tape handlers including IBM. They are supplied on high-performance Ampex Precision Reels or on custom reels. For application information write to Ampex Great Britain Limited, Arkwright Road, Reading, Berkshire, England. AMPEX

Detailed design and precision machining explain MAXAM quality and unfailing operation



Exploded for production engineers to appreciate its superior reliability, here is a pilot solenoid valve by MAXAM:-

1. ***Seats and Plunger*** — manufactured from plastic iron, heat-treated to provide maximum wear-resistance consistent with optimum electrical characteristics.
2. ***Encapsulated Coil*** — each one subjected to a 24-hour water immersion test before assembly. Available in a wide range of AC and DC voltages. Heat dissipation assisted by controlled medium passing through centre of coil.
3. ***Mounting Attachments*** — cast as an integral part of valve body.
4. ***Seals*** — of special synthetic rubber compound which resists the action of specified liquids and gases.
5. ***Operation*** — the valve can be arranged for two or three-way normally open, or normally closed operation.
6. ***Only 2 Moving Components*** — movement is confined to the plunger and spring, reducing wear (and consequently maintenance) to the minimum.

* ***Manifold Mounting*** — the valve body base can be drilled (drill-point recesses are provided) for mounting on a machined face.

* ***Compactness*** — overall height of the valve is only $3\frac{1}{16}$".

* ***Operating Pressures*** — range up to 250 p.s.i. depending on the valve arrangement and orifice size.

The design above is typical of the meticulous attention to detail and the superior care taken to ensure that MAXAM controls and air/hydraulic components shall work infallibly for as long as possible on the minimum upkeep cost. The whole assembly complies with the MAXAM emphasis on quality and reliability.

66% of current production from our machine shops is for companies whose designers — with experience of MAXAM product quality, performance and reliability — have planned their future flow production machines with MAXAM Controlled Fluid Power in mind!

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MA8

lated from the load, and the alternator connected to the load after the output has built up to the required voltage and frequency. On restoration of mains supply, allowing also for transient restorations, the load is disconnected from the alternator and reconnected to the incoming supply, and the engine is automatically stopped.

Provision is made for local control so that the engine may be exercised for maintenance purposes, and fault indicators and alarms to register engine defects such as failure to start, excessive engine temperature, or low lubricating-oil pressure, are fitted as required. Manufactured by Southern Instruments.

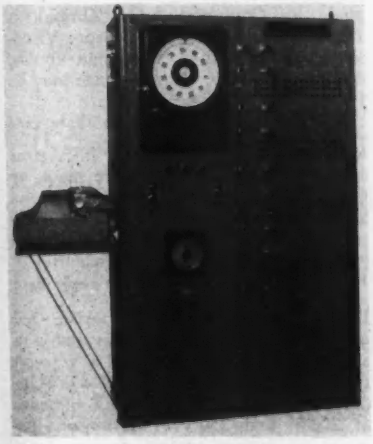
Circle **No 511** on reply card

TEMPERATURE LOGGER

automatic operation

An equipment by Foster Instrument automatically measures the temperature at up to 208 thermocouple stations in turn, and prints the index number of the station and its temperature on an electric typewriter. The scanning unit has five selector panels, each containing two 6-bank uniselectors. The uniselector panels are externally linked so that alterations may be made to the scanning sequence, and scanning may be continuous (average 5 seconds per station), or arranged to recur at preset time-intervals.

Alarm contacts may be fitted to indicate stations whose temperatures fall outside predetermined limits, and these may also be printed in red. Alternatively,



Easily altered scanning-sequence

the unit can scan continuously, and print only those temperatures outside the limits. The equipment is 5 ft 9 in high, 5 ft wide, and 1 ft 9 in deep.

Circle **No 512** on reply card

X-RAY SPECTROMETER

automatic print-out

A fully automatic X-ray fluorescence spectrometer is designed to analyse materials rapidly in a flexible routine. It will deal with any element having an atomic number of 12 (magnesium) or higher, and will analyse up to twenty elements in one operation. The instrument scans through the spectrum, and

Fully automatic operation; results are printed on the electric typewriter at the right of the console

is programmed to stop at the appropriate angle for each element.

The Hilger and Watts Fluorprint works on a ratio system, and pulses are counted during the accumulation of a preset number of counts on a monitor. Scintillation and flow-porportional counters are arranged to cover the whole range of an analysis, and no adjustment is needed. To change from one type of analysis to another it is only necessary to pull out the plug-board and substitute another covering the required program. An electric typewriter automatically prints the results obtained from the line intensities. Circle **No 513** on reply card

RADIO-ACTIVITY MONITOR

high sensitivity

A device by Elliott Nucleonics consists of an indicating unit and a sampling unit, the latter containing a Geiger-Müller tube surrounded by a bed of ion-exchange resin. Water is passed through the resin bed at a controlled rate, and dissolved solids, including any fission products present, are retained in the resin. (The sampling is normally carried out over a weekly period in which 20 litres of water are passed through the ion exchange resin at a controlled rate, after which the resin is replaced.)

The beta/gamma activity emitted by the solid radio-isotopes is detected by the Geiger tube, and the output is fed to the indicator. This records continuously the mean counting rate and, if required, actuates an alarm on reaching a predetermined level.

Circle **No 514** on reply card

EXPLOSIVE-GAS DETECTOR

electronic

This unit by I.E.C.-Sieger uses a detector consisting of an insulating material impregnated with appropriate catalysts, the detector being heated by a coil forming part of a balanced bridge circuit. The catalysts react to inflammable gases by increasing the temperature (hence the resistance) of the coils, thereby unbalancing the bridge. The range of catalysts used is claimed to cover all inflammable gases.

The output from the unbalanced bridge is fed to a transistor feedback amplifier, which operates a relay and the dual alarm system. A green indicator-lamp remains on so long as the detector circuits are unbroken, and a red lamp and electric bell indicate the presence of inflammable gas. Standard instruments are available to operate from 6, 12, or 24 V d.c. Circle **No 515** on reply card

pH INDICATOR

strip-chart recording

A combined pH meter and recorder by Analytical Instruments has a range of 2 to 12 pH, readily adjustable to 0 to 14 pH, with an accuracy better than 0·1 pH. The recorder carries a 63-ft chart, lasting for 31 days at 1 in/h. Other chart-speeds, up to 16 in/h, are available by a simple gear-change, and a front-panel switch permits disconnexion of the chart drive so that the instrument may be used as an indicating meter. The chart uses paper with pressure-sensitive coating. Circle **No 516** on reply card

HUMIDITY INDICATOR

rugged detector

A relative-humidity indicator by Lock uses a plastic sensing-element, the surface resistance of which varies logarithmically with changes in humidity; it is claimed that it is unaffected by most chemical vapours and will tolerate prolonged exposure to 100% relative humidity. A multi-point selector switch allows up to 6 elements to be connected in turn to one indicator. Elements may be used over the range -5 to $+80°C$, and have a temperature-coefficient of 0·2% r.h. per degF.

Calibration accuracy is given as $\pm 3\%$, and the scale covers 10 to 100% r.h. Two calibrations are available, one for use over the range 10–60% r.h., the other for use over 30–100% r.h. Response time is about 30 s to reach 67% of a given relative humidity change. An output of 0–10 μA d.c. is provided for recorders or remote-indicators.

Circle **No 517** on reply card

LIQUID-LEVEL CONTROLLER

conductivity operated

Intended for use with any liquid whose specific resistance does not exceed 50 kΩ/cm^3. Thomas Industrial Automation's Resistron has continuously variable sensitivity, and a change-over switch sets either high- or low-level control. Relay-

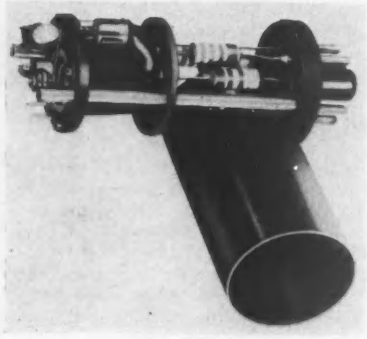
contact rating is 5 A, 250 V a.c., with one normally-open contact and one normally closed. The standard model will operate from 110, 240, or 440 V, 40–60 c/s, and two indicator lights (red and green) are fitted on the case lid.

Circle **No 518** on reply card

D.C. AMPLIFIER

phototransistor system

The Sangamo Weston Servo-pot is basically a d.c. amplifier using a phototransistor and galvanometer in a bridge circuit, the current output of which is directly proportional to the voltage input. The galvanometer vane intercepts a light-beam focused on the phototransistor, the



Small, light

position of the vane determines the amount of light falling on the phototransistor, hence its output.

The model S.44, form 5, is designed for operation from a 24 V d.c. supply, and has a standard output of 1 mA for an input of 10 mV. The base is an octal plug, and the case is approximately 3 in long by 1⅞ in diameter.

Circle **No 519** on reply card

ANALOGUE COMPUTERS

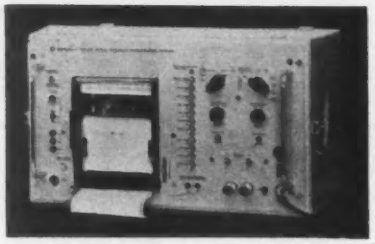
'do-it-yourself' system

The basis of Electronic Associates system is the TR-5 mounting unit, which makes it possible to assemble analogue computers for special purposes with minimum difficulty; the series of solid-state elements that are used in the Pace computer simply plug in to the mounting unit. This contains all the controls necessary to operate a 20-amplifier computer. It will house up to six computing components and a transistorized power-supply, and two expansion units are available: one provides space to accept five dual amplifiers, and the other space for ten dual or twenty single modules. Circle **No 520** on reply card

CHART RECORDER

high input-impedance

An improved model of the Rohde and Schwarz Enograph d.c. recorder is available from Aveley Electric. Features include an input impedance of up to 10^5 MΩ, a fully-floating input, and ten chart-speeds selected by push-button con-



Ten chart-speeds

trol. These are in the ratio 2 : 1 or 3 : 1, and may be selected from a range of speeds between 10 mm/s and 10 mm/h. Provision is also made for driving the chart from an external mechanism.

Four types of recording are provided: ink; ball-point pen; electrode; and stylus. It is claimed that the unit is particularly suitable for use when vibration is present, as in testing aircraft or motor vehicles. Circle **No 521** on reply card

LOW-FREQUENCY OSCILLATOR

transistorized

A battery-driven portable oscillator has two outputs at a nominal phase-difference of 90°, each of which is steplessly variable up to 0·3 V r.m.s. into 600 Ω.

Frequency range is 0·2 c/s to 20 kc/s; accuracy is given as ± 2% down to 20 c/s and ± 3½% down to 0·2 c/s, and output stability is ± 2 dB. Made by Nash and Thompson, the T11 weighs 8 pounds and measures 5 × 5 × 8 in overall. Circle **No 522** on reply card

PHOTO-ELECTRIC CELL

one-way sensitivity

A unit by Hird-Brown operates only when the light beam is broken in one direction, i.e., should an object pass through the beam in the opposite direction the unit ignores it. It is suitable for operation indoors or out, in a wide range of ambient temperatures, and will work from beams of length up to 75 ft.

The warning bell may be set on site to ring continuously, or to stop after 5 to 15 s, and further contacts are provided for the operation of emergency stops or controls.

Circle **No 523** on reply card

QUICK LOOKS

Transistor oscillator. The Solartron CO 1008, based on an original design by the Royal Radar Establishment, covers a frequency range of 20 c/s to 200 kc/s. Frequency may be set to an accuracy of ± 5% with the fine-control dial, and is held to within 0·2% of the set frequency over an 8-hour period. The output is continuously variable up to 1 V and contains less than 0·25% total harmonic distortion above 100 c/s, and less than 1% below 100 c/s.

Circle **No 524** on reply card

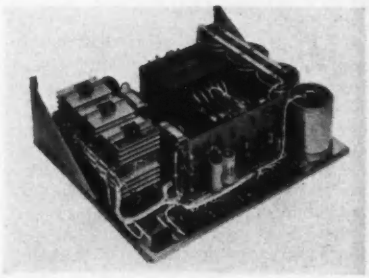
Plugs and sockets. A miniature wander plug and socket by A.E.I. Radio and Electronics Division is designed for printed-circuit mounting. The socket mounting-pin diameter is 0·05 in, and the socket can be mounted on a 0·2 in diameter centre using the standard 0·05 in mounting hole.

Circle **No 525** on reply card

Computer diodes. Gold-bonded silicon diodes made by Hughes Aircraft (U.S.A.) are available from Hughes International (U.K.). The guaranteed recovery-time is 0·5 mμs. Typical capacitance is 0·7 pF.

Circle **No 526** on reply card

Modular power-supplies. A range of 45 transistorized d.c. power-supplies is available from Invar Electronics (U.S.A.). Units are manufactured in 9 voltage-



ranges from 1 to 37 V, and in 5 power-ranges from 0·7 to 15 A. All models have 15 mV maximum line- and load-regulation, and a maximum ripple of 2 mV.

Circle **No 527** on reply card

Rotational viscometer. The Rheomatic 15, made by Contraves A.G. (Zürich), is available from Short and Mason. Viscosity range, related to Newtonian liquids, is 0·2 cP to 10^7 cP. Mains voltage may be 110 or 220 V, 50 c/s.

Circle **No 528** on reply card

Relief valve. Available with inlet sizes from 1¼ to 6 in, a relief valve made by Crosby Engineering uses both bellows and an auxiliary piston to provide back-pressure balancing. If either fails, the valve continues to operate efficiently.

Circle **No 529** on reply card

D.C. to d.c. converter. Transistorized units by Aveley Electric are available in a range of ratings from 5 to 120 W, with supply voltages from 6 to 24 V d.c. Standard output is 300 V d.c. with tappings at 200 V and 250 V. Polarity-sensitive relays to protect against damage from input-polarity reversal may be supplied in a variety of housings.

Circle **No 530** on reply card

Frequency meter. A unit by Firth Cleveland Instruments measures the frequency of signals in four ranges giving full-scale indication for 0·2, 2, 20, and 200 kc/s respectively. For inputs with amplitude between 0·075 and 10 V r.m.s. the accuracy of indication is within ± 2½% f.s.d.

Circle **No 531** on reply card

Air cylinders. A range of square-ended air cylinders by Schrader's can easily be fitted with interchangeable mountings. They can operate on pressures of 5 to 150 lbf/in², and bore sizes are available from 1¼ to 4 in. Piston rods are of

Chasing after the right transistor?

If the transistor you're after is a rare specimen with unusual characteristics you can go a long way before you finally pin it down. Give us an idea of the kind of specimen you are seeking and we may be able to give you the answer.

The list of Ediswan Mazda transistors is constantly growing; a request on your letterhead will bring you details of the very latest types.

This could be it!

If you are looking for a VHF pnp drift transistor, the XA131, a recent addition to our range, may be the one you want. It is suitable for use as a **Local Oscillator up to 250 Mc/s or an R.F. Amplifier up to a frequency of 100 Mc/s.**

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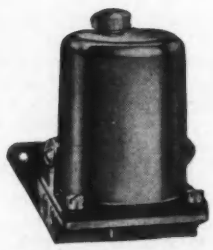
CRC 15/74

Circle No 92 on reply card for further details

TRANSMISSION CONTROL

"On plant" mercury-in-steel air-operated proportional temperature controller.
Publication No. R39



"On line" air-operated receiving controller. *Publication No. R31*

Mercury-in-steel air-operated temperature transmitter
with Polyester resin glass-fibre cover, stainless steel base, stem and bulb. *Publication No. T39.*

High thermal response. Wide range of temperatures.
Standard output air pressure, 3-15 p.s.i. Small and compact.

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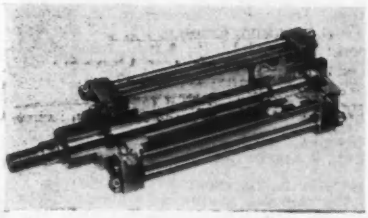


ground steel, and are supplied in standard strokes of 4–12 in (cushioned) and 1–12 in (non-cushioned).

Circle **No 532** on reply card

Tunnel diodes are announced by I.B.M. which are said to switch in times less than 4×10^{-12} s, and will require less power than present designs.

Circle **No 533** on reply card

Thermocouple connector. An oil- and water-tight plug and socket by West Instrument is made from materials such that temperature gradients over the plug do not generate spurious voltages. The connectors are polarized to prevent wrong connexion, and are suitable for use in equipment such as gas or steam turbines.

Circle **No 534** on reply card

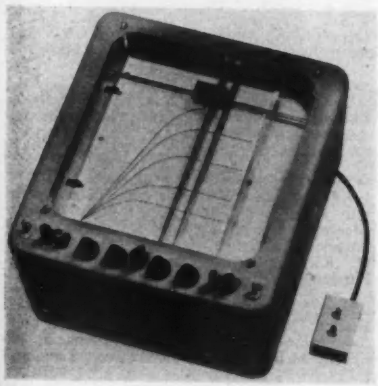
Thermo-electric cooling units using the Peltier effect are being made by Salford Electrical Instruments. Cooling capacities range from less than 1 W for a single junction to more than 10 W for a large multiple junction. The first of the group readily available is the BT.4, a 4-junction unit with a cooling capacity rated at 2 W. A typical application is the cooling of power transistors to increase their effective rating.

Circle **No 535** on reply card

Reducing valve. Hymatic Engineering's PAS.227 high-pressure reducing-valve has an inlet pressure range from 500 to 4000 lbf/in², while the output pressure is (400 ± 25) lbf/in² over a flow range from 5 to 65 ft³/min. The valve will accept an inlet-pressure increase from zero to 4000 lbf/in² in 2 ms, and will operate over the temperature range − 58 to + 110°C.

Circle **No 536** on reply card

X-Y Recorder. The Houston (U.S.A.) HR-93 recorder has an electric pen-lifting mechanism allowing point plotting, family curve tracing, and fast non-recording pen-indexing. Accuracy is given as



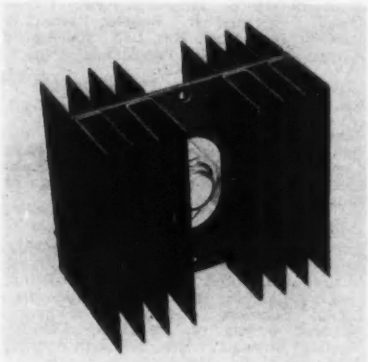
0·5% with a pen speed of 7·5 in/s on both axes. Amplifiers are interchangeable, and available with sensitivities of 10 mV/in or 1 mV/in for either or both axes.

Circle **No 537** on reply card

Miniature rotary potentiometer. A single-turn unit by Miniature Electronic Components has a maximum diameter of 0·5 in and an overall length of 1·14 in. It is available in ten standard ranges from 50 Ω to 50 kΩ, and will dissipate 1·5 W at 80°C; temperature range is − 55 to + 150°C. Weight is less than 10 grams.

Circle **No 538** on reply card

Heat sinks. Two models by Marston Excelsior have nominal thermal resisti-



vities of 1·75 degC/W and 2·5 degC/W respectively. The picture shows the 16-fin model, which has the higher dissipation.

Circle **No 539** on reply card

Silicon transistors. A range of *n-p-n* devices for use at medium to high frequencies is introduced by G.E.C. Frequencies are typically 15, 20, and 25 Mc/s for ST 721, 722, and 723 respectively. Maximum total dissipation is 250 mW at 50°C.

Circle **No 540** on reply card

Inductance bridge. Giving direct readings of inductance and *Q*, with or without d.c. flowing, a Hay bridge by Furzehill Laboratories operates over a frequency range of 25 to 3000 c/s. Four ranges cover inductance from 0·05 to 50 H (maximum frequency 3000 c/s), and a fifth range covers 50 to 500 H (maximum frequency 400 c/s). The polarizing d.c. must be supplied by an external source.

Circle **No 541** on reply card

High-voltage resistors by Welwyn are available in the range of values 2 to 5000 MΩ. Maximum operating-voltages are 10 kV d.c. continuous or 50 kV pulse. Load stability is better than 1%.

Circle **No 542** on reply card

Inclinometer. An electronic indicator registers gradients as small as 1″ (one second) of arc from the horizontal (i.e. 5 μ in/in). The Talyvel, made by Taylor, Taylor and Hobson, has three switched ranges covering gradients up to 50″, 100″, and 8′ respectively.

Circle **No 543** on reply card

INDUSTRIAL PUBLICATIONS

Seam welding. A brochure from Rockweld presents information on their Circomatic machine.

Circle **No 544** on reply card

Effluent and trade-waste instrumentation. Automatically controlled equipment by Lock is described in a recent leaflet.

Circle **No 545** on reply card

Non-destructive testing by various methods is described in an illustrated booklet from Solus-Schall.

Circle **No 546** on reply card

Relays. Current overload and underload relays are the subject of data sheet OR/UR from Elcontrol.

Circle **No 547** on reply card

Electromagnetic valves are described in an illustrated booklet from Londex.

Circle **No 548** on reply card

Furnaces. Roller-hearth, high-temperature hydrogen-atmosphere, and induction heating furnaces by G.E.C. are described in three leaflets designated E.75, E.78, and E.67 respectively.

Circle **No 549** on reply card

Patchboards by Sealectro are shown in their recent leaflet.

Circle **No 550** on reply card

Connectors. Plessey's U.K.-A.N. range is described in a 52-page brochure.

Circle **No 551** on reply card

'Air compressors for industry' is the title of leaflet CB.193 from B. E. N. Patents.

Circle **No 552** on reply card

Contract engineering facilities provided by Negretti and Zambra are featured in their booklet C.100.

Circle **No 553** on reply card

Digital computer. The solid-stab PB 250 by Packard Bell (U.S.A.) is the subject of a recent data sheet.

Circle **No 554** on reply card

Printed circuits are the subject of a 'designers handbook' from Tectonic Industrial Printers.

Circle **No 555** on reply card

Low-voltage supplies and current stabilizers are detailed in bulletin 60/6 from Joyce, Loebl.

Circle **No 556** on reply card

General catalogue. Fischer and Porter's new catalogue covers flowmetering transmitters and secondary indicators, recorders, controllers and integrators etc.

Circle **No 557** on reply card

Photo-electric control equipment by Elcontrol is listed in data sheet PR, issue 3.

Circle **No 558** on reply card

Teleprinters by Creed in use at Bakelite Ltd are described in publication 041-016-1E.

Circle **No 559** on reply card

Motors, motor tachogenerators etc, to standard frame-sizes, are shown in a series of broadsheets from Vactric.

Circle **No 560** on reply card

LOOKING AHEAD

Unless otherwise indicated, all events take place in London. B.C.S. British Computer Society. Brit.I.R.E. British Institution of Radio Engineers. I.E.E. Institution of Electrical Engineers. I.Mech.E. Institution of Mechanical Engineers. I.S.A. Instrument Society of America. R.Ae.S. Royal Aeronautical Society. S.I.T. Society of Instrument Technology.

TUESDAY 13 DECEMBER
Analytical instrumentation of process gas streams by J. C. Hawkes. 7.30 p.m. Blossoms Hotel, Chester. Details: A. V. Bailey, 2 Finney Drive, Wilmslow, Cheshire. (I.Chem.E.).

WEDNESDAY 14 DECEMBER
Speed control of aircraft gas turbines for jet propulsion by R. J. Walsh and R. W. Haigh. 7 p.m. S.I.T.

FRIDAY 16 DECEMBER
The physics and general applications of semiconductor devices. 7 p.m. in the Lecture Theatre, The Byng Kenrick Suite, New College of Technology, Gosta Green, Birmingham 4. Details: W. Birtwistle, 78 Shaw Road, Rochdale, Lancs.

WEDNESDAY 4 JANUARY 1961
Automatic techniques in civil air line communications systems by W. E. Brunt. 6.30 p.m. Brit.I.R.E., London School of Hygiene and Tropical Medicine, Keppel St., London, W.C.1.

THURSDAY 5 JANUARY 1961
An informal discussion on *The reliability of mechanical engineering parts of data processing systems.* 10.30 a.m. Main Meeting Hall, I.Mech.E.

MONDAY 9—WEDNESDAY 11 JANUARY 1961
7th National Symposium on Reliability and Quality Control. Bellevue-Stafford Hotel, Philadelphia, Pa., U.S.A. Details: R. Brewer, G.E.C. Research Laboratories, Wembley, Middx.

MONDAY 16—FRIDAY 20 JANUARY 1961
Physical Society Exhibition. R.H.S. Halls, Westminster, London, S.W.1. (Probable dates).

TUESDAY 17—THURSDAY 19 JANUARY 1961
I.S.A. Instrument-Automation Conference and Exhibition. Sheraton-Jefferson Hotel, and Kiel Auditorium, St. Louis, Mo., U.S.A. Details: Wm. H. Kushnick, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

WEDNESDAY 18 JANUARY 1961
A general method of digital network analysis particularly suitable for use with low-speed computers by M. N. John. 5.30 p.m. I.E.E.
Digital computers in power system analysis by P. P. Gupta and Professor M. W. Humphrey Davies. 5.30 p.m. I.E.E.

MONDAY 23 JANUARY 1961
Cybernetics by Professor J. C. West. Royal Institution, Colquitt St., Liverpool. 6.30 p.m. I.E.E.

TUESDAY 24 JANUARY 1961
Discussion on *Machine-tool control.* Opened by E. H. Frost-Smith. 5.30 p.m. I.E.E.

TUESDAY 31 JANUARY 1961
Instrumentation past, present and future by L. S. Yoxall. 7 p.m. S.I.T.

WEDNESDAY 8 FEBRUARY 1961
Flight testing of v.t.o.l. aircraft by T. W. Brooke-Smith. 7.30 p.m. R.Ae.S., 4 Hamilton Place, W.1.

WEDNESDAY 15—FRIDAY 17 FEBRUARY 1961
1961 International Solid-state Circuits Conference. University of Pennsylvania and the Sheraton Hotel, Philadelphia, Pa., U.S.A.

MONDAY 16 FEBRUARY 1961
Transistors and all that by L. J. Davies. Central Hall, Westminster. I.E.E.

TUESDAY 17— SATURDAY 21 FEBRUARY 1961
24th International Components Show, Parc des Expositions, Paris, France.

4th International Exhibition of Electronic Components. Details: F.N.I.E., 25 Rue de Lubeck, Paris 16, France.

MONDAY 20—SATURDAY 25 FEBRUARY 1961
International Convention on Semi-Conductor Devices. Details: Société Francaise des Electroniciens et des Radioélectriciens, 10 Avenue Pierre-Larousse, Malakoff (Seine) France.

FRIDAY 3 MARCH 1961
Helicopter Approach Aids by H. W. Mitchell and S. G. Lennox. 7 p.m. R.Ae.S., 4 Hamilton Place, W.1.

TUESDAY 7 MARCH 1961
Guided weapon control equipment by John Dent. 6 p.m. R.Ae.S., 4 Hamilton Place, W.1.

WEDNESDAY 8—FRIDAY 10 MARCH 1961
11th Annual I.S.A. Conference on *Instrumentation for the Iron and Steel Industry*, Roosevelt Hotel, Pittsburgh, Pa., U.S.A. Details: Richard R. Webster, Jones & Laughlin Steel Corp. Res. Lab., 900 Agnew Avenue, Pittsburgh 30, Pa., U.S.A.

MONDAY 20— THURSDAY 23 MARCH 1961
I.R.E. National Convention, New York.

TUESDAY 21—SATURDAY 25 MARCH 1961
10th Electrical Engineers Exhibition, Earls Court. Details: Mr Joyce, Electrical Engineers Exhibition, 6 Museum House, 25 Museum St., London, W.C.1.

MONDAY 27—FRIDAY 31 MARCH 1961
3rd Symposium on *Temperature—Its measurement and control in science and industry.* Veteran's Memorial Hall and Deshler-Hilton Hotel, Columbus, Ohio, U.S.A. Sponsors: I.S.A. American Institute of Physics, National Bureau of Standards. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

LOOKING FURTHER AHEAD

MONDAY 17—WEDNESDAY 19 APRIL 1961
7th National U.S.A. Symposium on *Instrumental methods of analysis.* Shamrock-Hilton Hotel, Houston, Texas, U.S.A. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

THURSDAY 20 APRIL 1961
All-day symposium on *Air Traffic Control.* R.Ae.S., 4 Hamilton Place, W.1.

THURSDAY 20 APRIL—THURSDAY 4 MAY 1961
Engineering, Marine, Welding and Nuclear Energy Exhibition, Olympia.

SUNDAY 30 APRIL—THURSDAY 4 MAY 1961
7th National aero-space instrumentation symposium. Adolphus Hotel, Dallas, Texas. Details: W. J. Gabriel, Convair Division, General Dynamics Corp, Ft. Worth, Texas, U.S.A.

WEDNESDAY 3—SATURDAY 13 MAY 1961
British Columbia International Trade Fair, Exhibition Park, Vancouver, Canada.

MONDAY 8—WEDNESDAY 10 MAY 1961
4th National I.S.A. Power Instrumentation Symposium. La Salle Hotel, Chicago, Ill., U.S.A. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

TUESDAY 9—WEDNESDAY 17 MAY 1961.
International Exhibition of Measurement, Control, Regulation and Automation (Mesucora) and 58th Exhibition of French Physical Society, C.N.I.T., Paris. Secrétariat Général, 40, rue de Colisée, Paris, 8, France.

WEDNESDAY 10—FRIDAY 12 MAY 1961
Pulp and Paper Instrumentation Symposium. Northland Hotel, Green Bay, Wisc., U.S.A. Sponsors: I.S.A. and T.A.P.P.I. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

FRIDAY 19 MAY—SUNDAY 4 JUNE 1961
British Trade Fair, Moscow. Details: Industrial and Trade Fairs Ltd., Russell Street, London, W.C.2.

MONDAY 22—WEDNESDAY 24 MAY 1961
10th National Telemetering Conference. Hotel Morrison, Chicago, Ill., U.S.A., Sponsors: I.S.A., A.I.E.E., A.R.S., I.A.S., I.R.E. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

TUESDAY 30 MAY—2 JUNE 1961
Radio and Electronic Component Show, Olympia. Details: Industrial Exhibitions Ltd., 9 Argylle St., London, W.1.

TUESDAY 6—THURSDAY 8 JUNE 1961
I.S.A. Summer Instrument-Automation Conference and Exhibition, Royal York Hotel and Queen Elizabeth Hall, Toronto, Ont., Canada. Details: Wm. H. Kushnick, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

MONDAY 12 JUNE 1961
Air Pollution Instrumentation Symposium (with the June 12–16 annual meeting of the Air Pollution Control Association), Hotel Commodore, New York City, N.Y., U.S.A. Sponsors: I.S.A. and APCA. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

MONDAY 12—SATURDAY 17 JUNE 1961
Conference on *Components and materials used in electronic engineering.* Central Hall, Westminster, I.E.E.

TUESDAY 13—FRIDAY 16 JUNE 1961
3rd Biennial International Gas Chromatography Symposium, Kellogg Center, Michigan State University, East Lansing, Mich., U.S.A. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

MONDAY 26 JUNE—SATURDAY 1 JULY 1961
International Measurements Conference, (Imeko), Budapest. Details: Prof. J. F. Coales, Cambridge University, Trumpington St., Cambridge, or Imeko Secretariat, Budapest 5, P.O.B. 3.

WEDNESDAY 28—FRIDAY 30 JUNE 1961
2nd Joint Automatic Control Conference. University of Colorado, Boulder, Colo., U.S.A. Sponsors: I.S.A., A.I.Ch.E., A.I.E.E., A.S.M.E., I.R.E. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

WEDNESDAY 30 AUG—WEDNESDAY 6 SEPT 1961
Annual Meeting, British Association for the Advancement of Science, Norwich. Details: Secretary, B.A.A.S., 19 Adam Street, Strand, London, W.C.2.

MONDAY 4—SATURDAY 9 SEPTEMBER 1961
3rd International Sessions of the International Association for Analogue Computation. Belgrade, Yugoslavia. Details: Yugoslav Committee for Etan Terazije 23/VII, Belgrade, Yugoslavia.

MONDAY 4—SUNDAY 10 SEPTEMBER 1961
S.B.A.C. Flying display and exhibition, Farnborough. Details: S.B.A.C., 29 King St., St. James, London, S.W.1.

WEDNESDAY 6—FRIDAY 8 SEPTEMBER 1961
International Symposium on the *Transmission and processing of information.* Massachusetts Institute of Technology. Submission of papers is invited. Details: R. M. Fano, R.L.E., M.I.T., Cambridge 39, Mass., U.S.A.

Joint Nuclear Instrumentation Symposium. North Carolina State College, Raleigh, N.C., U.S.A. Sponsors: I.S.A., A.I.E.E., I.R.E. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

MONDAY 11 SEPTEMBER 1961
20th International Congress of Navigation. Baltimore. Details: Permament International Association of Navigation Congresses, 60 rue Juste Lipse, Brussels.

MONDAY 11—FRIDAY 15 SEPTEMBER 1961
I.S.A. Instrument-Automation Conference and Exhibition and I.S.A.'s 16th Annual Meeting. Memorial Sports Arena, Los Angeles, California, U.S.A. Details: Wm. H. Kushnick, I.S.A., 313 Sixth Avenue, Pittsburgh, 22, Pa., U.S.A.

WEDNESDAY 4 OCT—THURSDAY 12 OCT 1961
Second Electronic Computer Exhibition and Symposium, London. Details: Mrs. S. S. Elliott, M.B.E., 64 Cannon Street, London, E.C.4.

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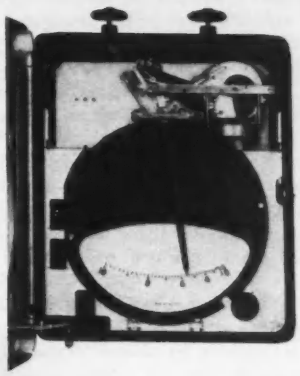

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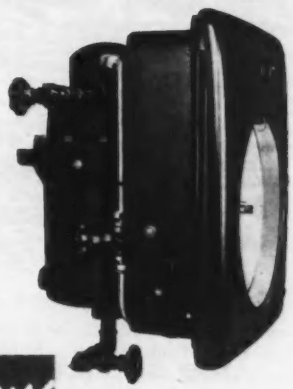

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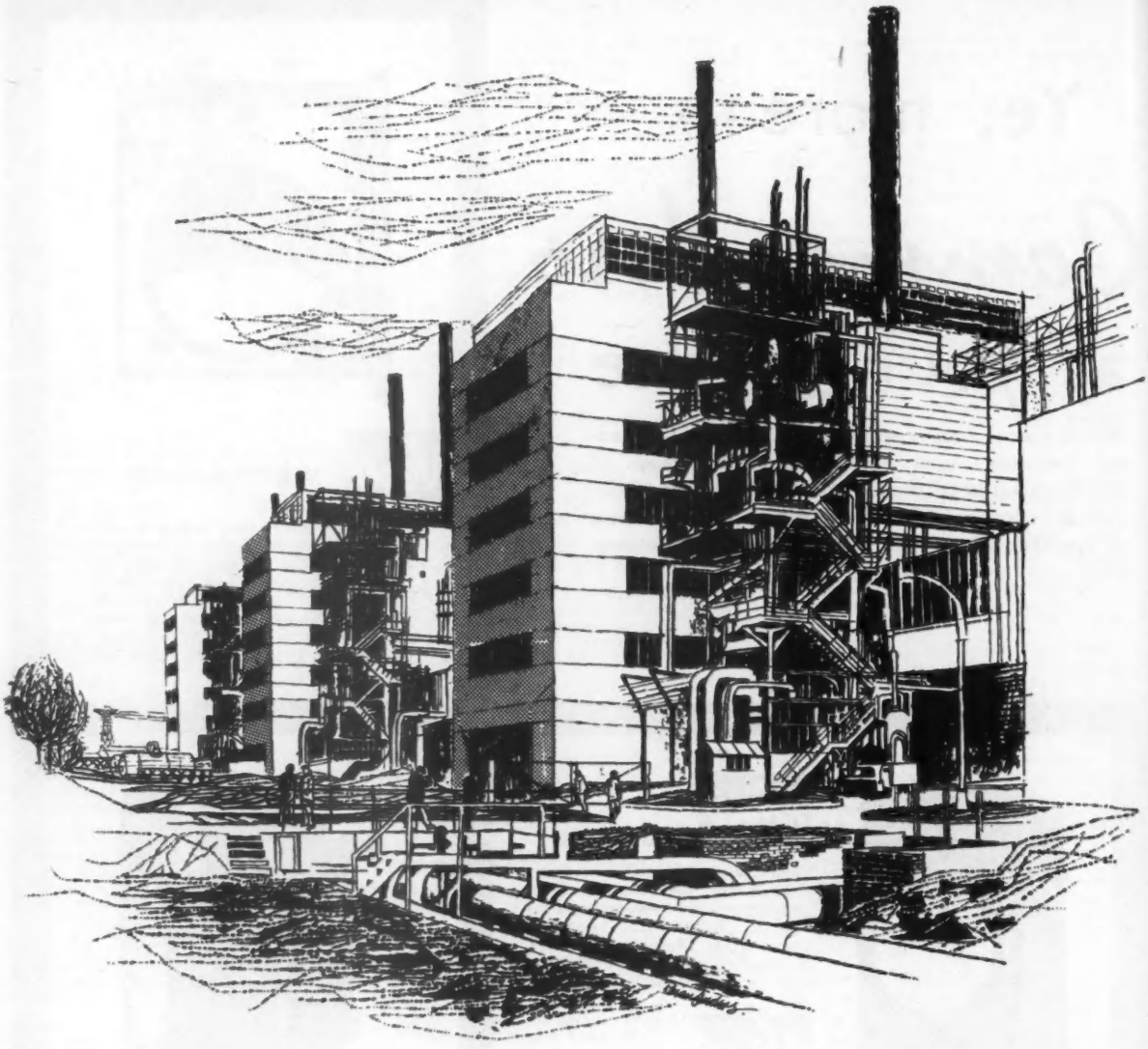

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Book Reviews

Networks

Introduction to Modern Network Synthesis *by* **M. Van Valkenburg.** *John Wiley & Sons, New York: Chapman & Hall, London. 1960. 498 pp. £4 14s.*

This book can be divided into two almost equal parts, the first dealing with introductory material and synthesis of one-terminal-pair networks, and the second with synthesis of two-terminal-pair networks. Topics discussed in the first part include network analysis, positive real functions, testing driving-point functions, relationships between parts of network functions, two- and three-element synthesis of one-terminal pairs, and frequency-domain approximations. The second part consists of seven chapters which deal with open-circuit, terminated, and double-terminated networks, and includes a chapter on image parameter synthesis and a chapter on Butterworth, Chebyshev, and maximally flat delay approximations. At the end of each chapter there is a set of examples (without answers) and an annotated list of references for further reading.

The subject matter is presented in an interesting manner and a concise form, and important results arrived at in the text are conveniently summarized in tables. Explanations are clear and the order of presentation logical, and each topic is discussed at sufficient length for complete understanding. The chapters on positive real functions and testing driving-point functions are especially clear, as is the chapter on two-terminal-pair synthesis by ladder development.

The book is written for students at an advanced undergraduate or beginning postgraduate level. It is an excellent introductory text.

D. G. WATTS

Circuits

Electronic Circuits, Signals, and Systems *by* **Samuel J. Mason** *and* **Henry J. Zimmermann.** *John Wiley & Sons, New York: Chapman & Hall, London. 1960. 616 pp. £5*

This book is a welcome addition to the M.I.T. 'Core Curriculum' in Electrical Engineering and forms a companion volume to the same authors' 'Electronic Circuit Theory' published in 1959. In the earlier volume the authors stressed the model concept of electronic circuits, and extensively used graphical interpretations of analysis. The new volume presents matrix, topological and signal-flow-graph methods of both circuit and system analysis.

After a brief introductory chapter in which the scope of the book is summarized, the reader is introduced to the method of handling the linear equations of circuit analysis by means of matrix algebra. The account given of the algebra itself is sketchy but adequate for the authors' purposes, though a reader interested in this subject might well seek a more complete and rigorous presentation. For example, a matrix is defined simply as 'a rectangular array of elements', a definition which may be considered somewhat less than mathematically precise. In the discussion of the application to practical analysis, attention is confined to the formulation of the circuit equations on a 'nodal' basis.

The chapter which follows is concerned with the relationship between a network transmission (i.e. the ratio of meter reading to source value for a meter and source attached to a network at two specified terminal pairs) and the topology of the network. The topology of linear graphs is a vast subject, but the few topological concepts needed to establish this relationship are lucidly presented. In following chapters the simple topological method of analysis is developed and a background of flow-graph theory and technique built up. This 'cause and effect' approach is then applied to a number of practical circuits and systems, both ground-node and loop-current bases of analysis being considered.

The authors then turn to the subject of signal analysis, the development of which takes up the bulk of the remaining and greater 'half' of the book. They begin with a general discussion of additive signal components as a background to a thorough presentation of Fourier analysis. The correlation concept is introduced at some length for the purpose of providing a unified approach to periodic, pulse, and random signals.

Consideration is then given to the transmission of signals through linear systems. The linear systems used as examples are all linear incremental models of electric or electronic circuits, but important properties are well displayed and the models selected well illustrate the generalities of the methods employed. These are extended to non-linear and time-varying-linear systems, and though the modulation functions described remain quite general, a generous number of practical physical cases are thoroughly investigated.

A final chapter gives an outline introduction to the concept of negative feedback. This chapter is comparatively short and concludes with the analysis of a two-stage transistor feedback amplifier. Control engineers would no doubt welcome an extension of this chapter to considerably greater length.

The authors have provided problems for solution by the reader at the end of each chapter. The index is adequate, but references are sparse, being confined to some eleven books recommended for general reading in the preface. The book is well printed and the illustrations are generous and of a high standard, though in a number of cases they could have been more happily 'married' to the text. The 'Core Curriculum' series has in the past provided a first-class and comprehensive approach to the field of electrical engineering; this new volume well maintains the standard set by its predecessors.

H. GRAHAM FLEGG

Systems

Control Systems Engineering. *Edited by* **William W. Seifert** *and* **Carl W. Steeg, Jr.** *McGraw-Hill Publishing Co. Ltd. 1960. 964 pp. £5 16s. 6d.*

A more apt title would be *Mathematical Techniques in Control Engineering*, since there is very little space devoted to engineering topics. The main virtue of the book is that many of the mathematical subjects used in the analysis and synthesis of complex systems, which at present exist in the form of technical papers, are integrated into one textbook. The treatment is not rigorous enough for the mathematician, and is intended primarily for the engineer. If the latter uses the book as an introduction to a mathematical technique, he will probably be disappointed by the fact that its effective application to a practical problem is not demonstrated. A good feature is the list of references at the end of each chapter.

In addition to the two co-editors there are nine other authors covering the seventeen chapters, and this results in some variation in quality and coverage of particular topics. The first two chapters discuss in general terms the analysis and synthesis of systems and the concept of models. Special reference is made to the various forms of mathematical models, and this leads logically to the detailed discussions on mathematical techniques given in the remaining chapters.

The main mathematical content includes the following: a good survey of ordinary differential equations including non-linear types of second and higher order; transform calculus; simple treatment of matrix theory; numerical analysis; linear integral equations (Volterra and Fredholm); statistical theory and a simple introduction to games theory. A significant omission is complex variable theory and this is therefore

not included in the discussion on Fourier and Laplace Transforms in (Chapter 4) dealing with linear systems.

Mathematical techniques applied to control systems also include the following. One chapter is devoted to introductory feedback theory, which could have been left out as there are several significant omissions. Asymptotic gain plots are mentioned, but no reference is made to Bode's equations and the restriction of their application to minimum-phase networks. Moreover trial and error compensation procedures are not described. Analogue computer techniques are briefly surveyed in another chapter, and in particular there is a good treatment of the synthesis of rational transfer functions. Phase-plane techniques and describing-function analysis are also described. Two approximation methods for the extension of the describing function to deal with statistical inputs are mentioned. However, no reference is made to the dual-input describing-function technique. Two chapters are devoted to the engineering application of statistical theory and to the optimization of linear systems. Newton's method of dealing with dynamic constraints and Booton's work on the specific time domain criterion for the optimum linear operator is included. One chapter describes time-varying non-linear systems and includes some new material. A method is described for synthesizing a terminal controller to achieve a desired response at one time only. The analysis of sampled-data systems is given in another chapter including random signal response. Synthesis procedures are not considered in detail.

The book is well presented and illustrated, and with its wide coverage of mathematical topics should form a handy reference source for the advanced worker in the control field. The serious student, however, will wish to have a more rigorous treatment of some topics, and will probably prefer reference to original mathematical texts and papers. R. J. A. PAUL

Transductors

Der Transduktor ein Baustein der Automatisierung *by* **Wilhelm Kafka.** *R. v. Decker's Verlag. 1960. 138 pp. DM15.*

The purpose of this little book (in German) is to acquaint the 'non-electrical' plant engineer with the principles of the transductor and magnetic amplifier, and with their application to control loops in modern plants.

Since the plant engineer will not be required to design magnetic amplifiers, but rather to select them from existing ranges of equipment, mathematics have rightly been kept to a minimum, and through the colloquial style of writing an exceptionally readable book has been created. This aspect is further enhanced by a smallish, but convenient format, and well spaced presentation of text and illustrations.

The book may clearly be divided into two main parts—the *principle* and the *application* of the magnetic amplifier—the latter section being re-inforced by some well chosen examples. The book will thus enable a plant engineer, be he mechanical or chemical, to assess whether a particular problem may be solved by the application of a transductor.

An enterprising publisher may do well to produce an English version of this excellent little book which forms part of a series of a similar type on various aspects of automation.

ERNEST D. MAY

Translation

Automatic Translation *by* **D. Yu Panov.** *Pergamon Press. 1960. 73 pp. £1 1s.*

This excellent little book is a description of the main ideas in machine translation as they were seen by the Russian workers in 1956, although additional material has been added to the translated edition to bring the main ideas up to date. The introductory chapter takes the form of a potted history of 'm.t.' and is interesting because it shows how the subject appears to an expert who is not a partisan of any particular western school. The objective and hard-hitting comment on a much-publicized American demonstration is a salutary comment upon one of the less fortunate aspects of our system, but the inevitable reference to the 'true invention' of m.t. by P. P. Troyansky in 1933 would be more credible if it were not accompanied by the remark that his proposals were not carried out because 'automatic installations suitable for the purpose had not yet been created'. The remainder of the book contains a lucid and factual account of the structure and programming arrangements for the B.E.S.M. computer which is used for Russian experiments in translation, and this is followed by chapters on dictionary construction and on the detailed translation programs. There is a speculative chapter on the problems which would be encountered in translating such languages as Chinese and finally a detailed example of an English-Russian translation.

It is pleasant to record that the book is most clearly written and that the translation and editing are excellent. It can be thoroughly recommended to specialist and layman alike.

A. D. BOOTH

Signals

Statistical Theory of Signal Detection *by* **Carl W. Helstrom.** *Pergamon Press. 1960. 364 pp. £3 3s.*

This is a mathematical text for the postgraduate student or research worker, interested in the application of statistical methods to decision, estimation and resolution problems in the detection of weak radar echoes (i.e. in signals of known shape, but subject to variations in such parameters as time of arrival, amplitude, phase, etc.). The author's objective is to define, and hence to synthesize, optimum systems for the detection of such signals.

The general approach adopted is to (i) specify hypotheses to be tested, and the measurement to be used in deciding among them, (ii) define a 'decision criterion' by which the most likely hypothesis is selected, (iii) apply the decision criterion to measured data to produce a decision strategy, and (iv) test the usefulness of the decision strategy by computing the probability of incorrect decisions, the variance of parameter estimates, etc. The greater part of the book is devoted to the discussion of applications of this general procedure to radar detection problems of graded complexity, starting with the simple decision problem of choosing between two hypotheses H_0 (that a signal is absent, and a given record is composed entirely of noise) and H_1 (that a signal is present in the given record), and proceeding to parameter estimation and signal detection for signals in 'clutter'.

It is claimed in the preface that 'the book should be easily understood by first-year graduate-students in mathematics, electrical engineering, or physics'. The engineer or physicist would probably need to resort to supplementary mathematical reading (particularly of statistical theory, and the theory of integral equations) to achieve the greatest value from this text. It is simplified by an excellent bibliography. R. A. WOODROW

Literature Received

Automatic Programming. *Edited by* **Richard Goodman.** *Pergamon Press Ltd. 1960. 300 pp. £3 3s.* ★ 704

Analogue Computers *by* **I. I. Eterman.** *Pergamon Press Ltd. 1960. 264 pp. £2 10s.* ★ 705

Principles of Control Systems Engineering *by* **Vincent del Toro** *and* **Sydney R. Parker.** *McGraw Hill Publishing Co. Ltd. 1960. 686 pp. £5 12s. 6d.* ★ 706

Basic Synchros and Servomechanisms, Parts 1 & 2. *Van Valkenburgh Nooger & Neville Inc. The Technical Press. 1960 Pt. 1 117 pp. Pt. 2 114 pp. 14s. per part.* ★ 707

Electronic Equipment Reliability *by* **G. W. A. Dummer** *and* **N. Griffin.** *Sir Isaac Pitman & Sons Ltd. 1960. 274 pp. £2 5s.* ★ 708

Principles of Servomechanisms *by* **A. Tyers** *and* **R. B. Miles.** *Sir Isaac Pitman & Sons Ltd. 1960. 176 pp. £1 5s.* ★ 709

Methods of Feasible Directions *by* **G. Zoutendijk.** *D. Van Nostrand Co. Ltd. 1960. 126 pp.* ★ 710

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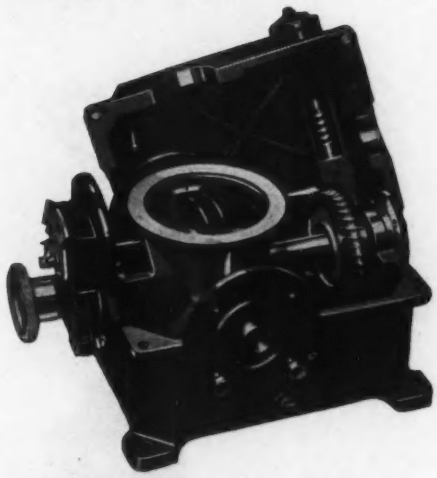

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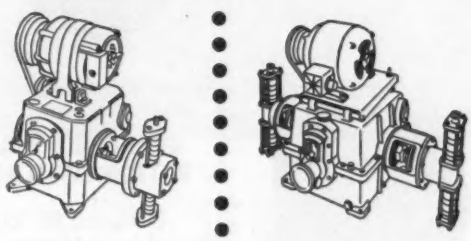

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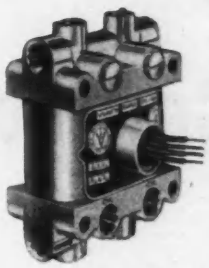

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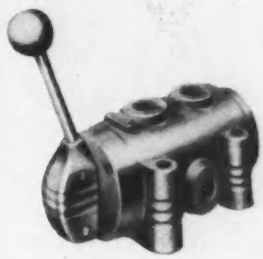

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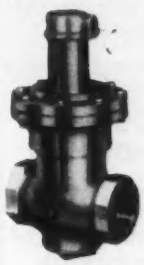

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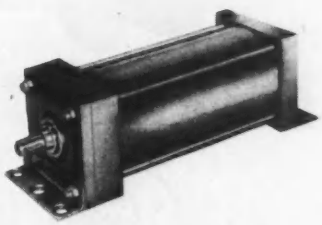

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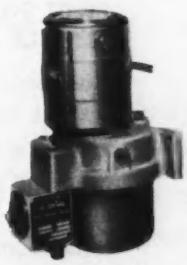

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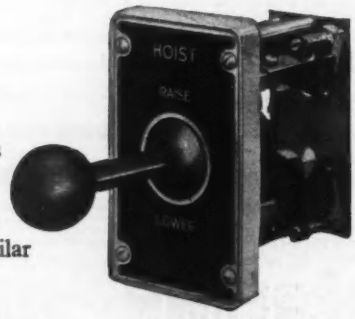

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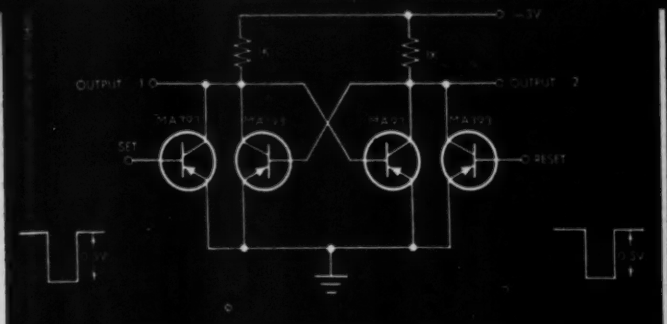

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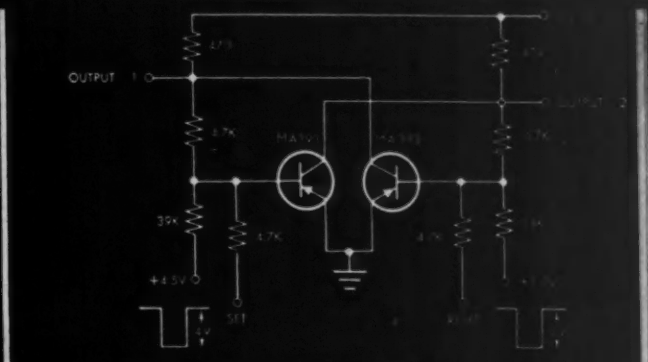

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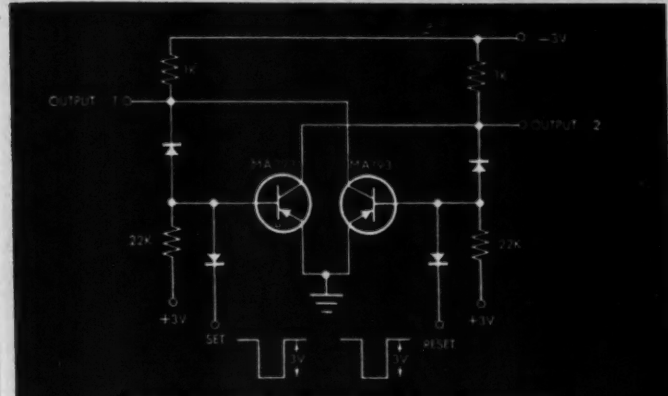

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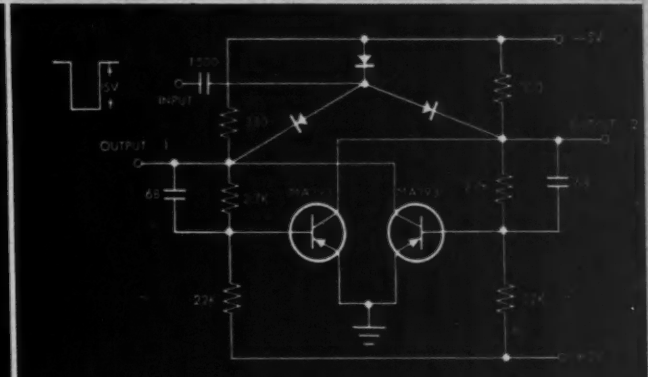

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The Semiconductors Micro Alloy Transistor (MAT) has proved its complete reliability in millions of operating hours in every type of computer logic circuit up to 5 Mc/s. It combines all the advantages of high frequency performance with low price. The MAT is easily designed into any logic circuit and offers the designer these important advantages:

- High beta
- High speed
- Low saturation voltage
- High V_{EB} rating
- Low I_{CO}
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Semiconductors Limited

For data sheets write to:
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Telephone: SWINDON 6421

One of the **Plessey** Group of Companies

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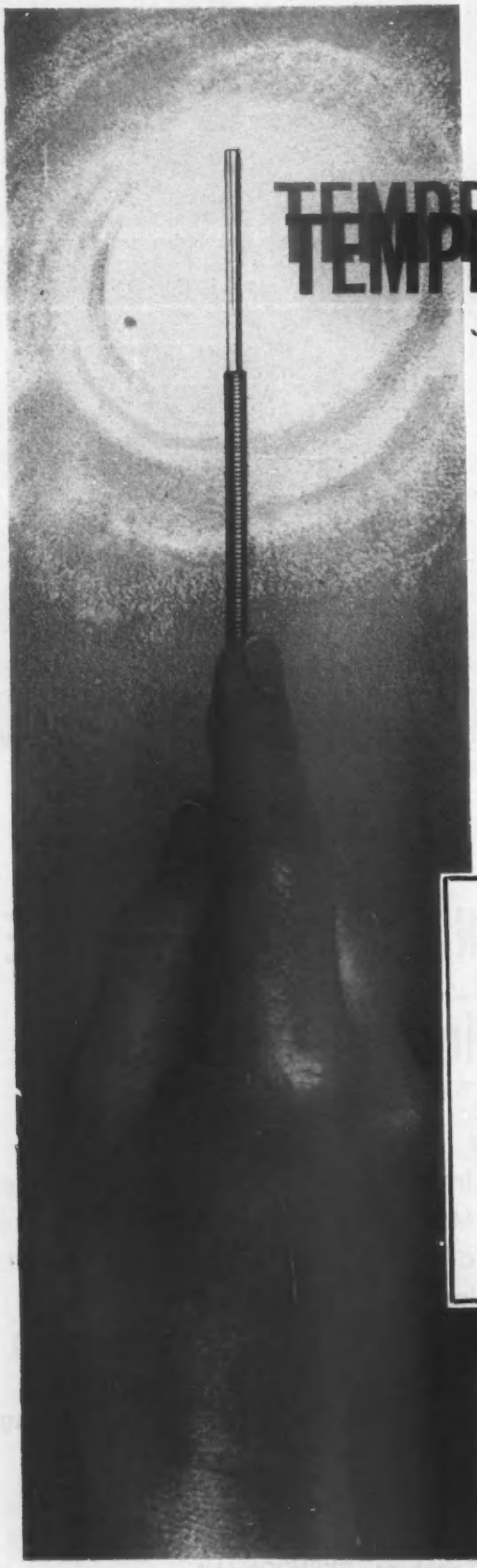


TEMPERATURE CONTROL

more efficient and reliable with the

AIRMEC

TEMPERATURE CONTROL UNIT

EFFICIENT ELEMENT

- Very small—hence high sensitivity
- Platinum wire type—hence high stability
- No moving contacts—hence high reliability

SENSITIVITY

Relay will operate on 0.1% change in resistance of element. This represents 0.4°C at 100°C.

TEMPERATURE RANGES

RANGE 1		−80°C	to	−15°C
2		−15°C	to	100°C
3	+	100°C	to	300°C
4	+	300°C	to	500°C

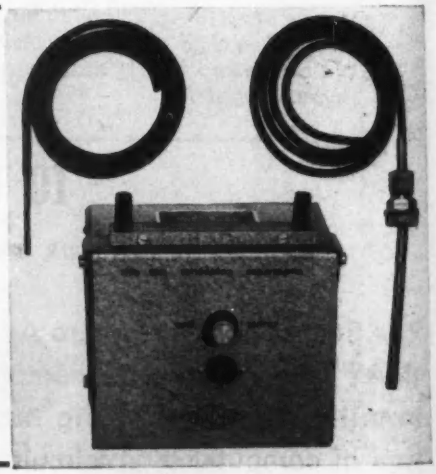
AIRMEC

TEMPERATURE CONTROL UNIT

No. N241

Price £19.15.0

IMMEDIATE DELIVERY



Airmec

AIRMEC LIMITED · HIGH WYCOMBE · BUCKS

Telephone: High Wycombe 2501-7

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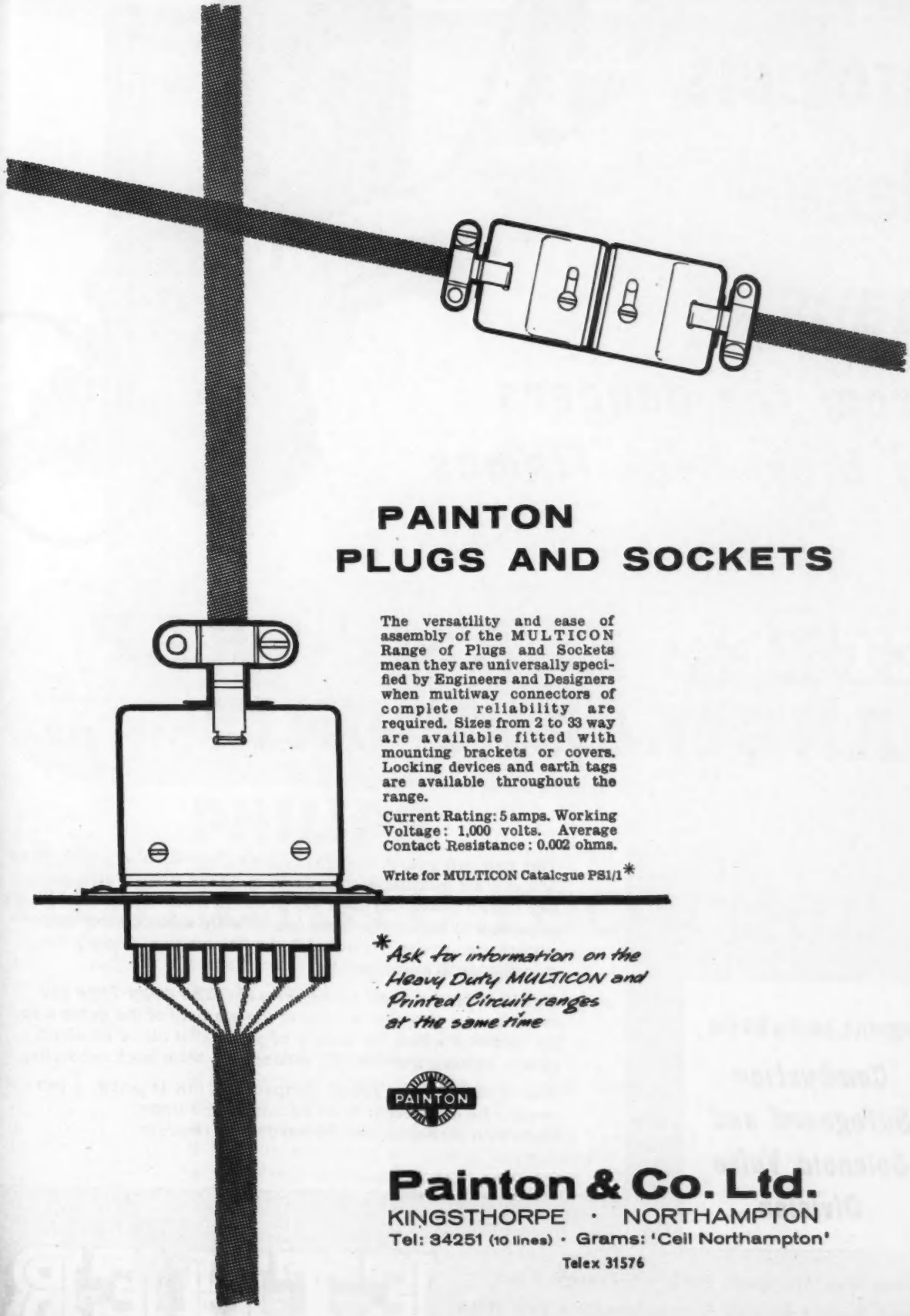

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The versatility and ease of assembly of the MULTICON Range of Plugs and Sockets mean they are universally specified by Engineers and Designers when multiway connectors of complete reliability are required. Sizes from 2 to 33 way are available fitted with mounting brackets or covers. Locking devices and earth tags are available throughout the range.

Current Rating: 5 amps. Working Voltage: 1,000 volts. Average Contact Resistance: 0.002 ohms.

Write for MULTICON Catalogue PS1/1*

Ask for information on the Heavy Duty MULTICON and Printed Circuit ranges at the same time

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protects flame-traps

from the dangers of blow-back flames

ETHER FLAME-TRAP ANCILLARY UNIT

Patent applied for

TYPE 350

This new safeguard, the ETHER Flame-Trap Ancillary Unit, Type 350, will be invaluable in industries where pre-aerated gas or pre-mixed gases are used. At present, a flame-trap is normally provided to arrest the flame temporarily when a blow-back occurs, but unless it is noticed, the flame will ultimately burn through the flame-trap.

Now this hazard need no longer exist. The ETHER Type 350 introduces a detector in front of the element of the flame-trap by means of which the supply of gas is shut off, or an alarm given, within a fraction of a second of a blow-back occurring.

The Type 350 is foolproof, compact and low in price. It can readily be adapted to fit all existing flame-traps. Illustrated technical data forwarded on request.

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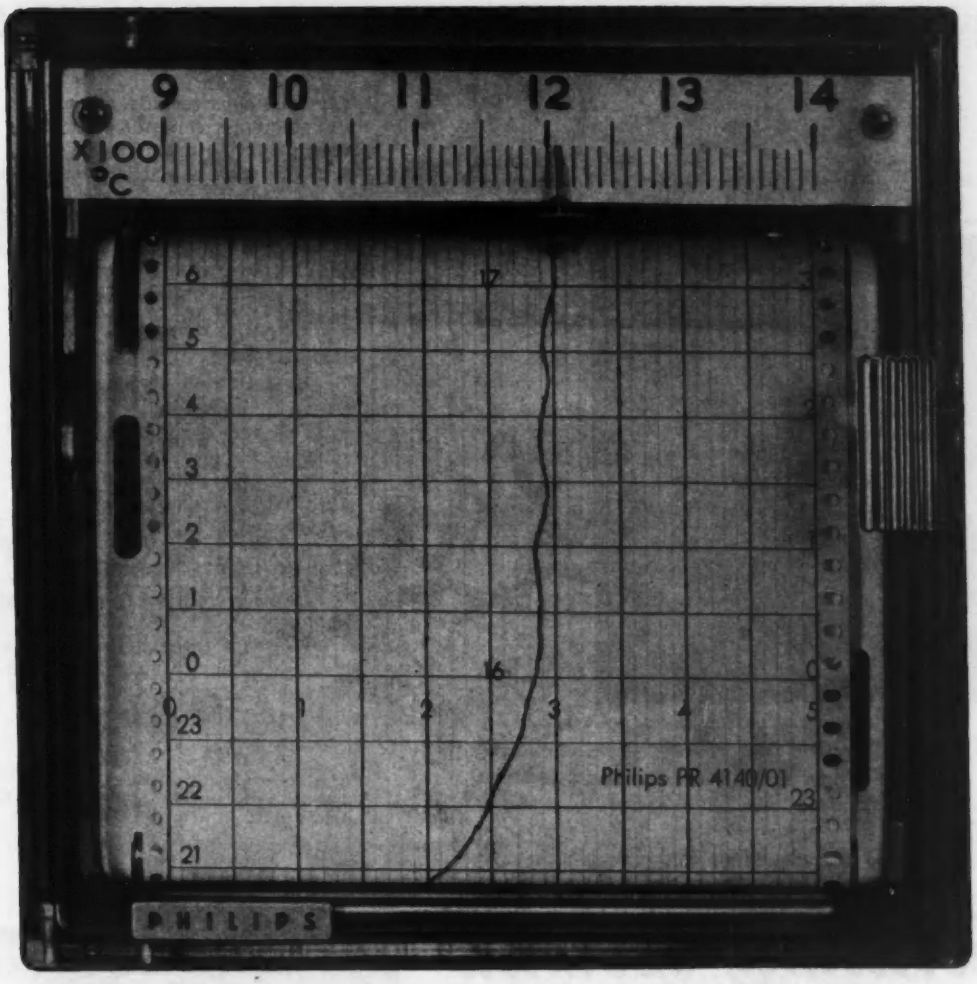
Tyburn Road, Erdington, Birmingham, 24 : East 0276-8
Representatives throughout U.K.; agents in all principal countries.

ETHER LIMITED



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miniature recorder

for mV and temperature measurements
Type PR 2400 A

- Reliable null-balancing potentiometer system.
- Easily interchangeable ranges.
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Overseas inquiries: N.V. PHILIPS' GLOEILAMPENFABRIEKEN - EINDHOVEN - HOLLAND

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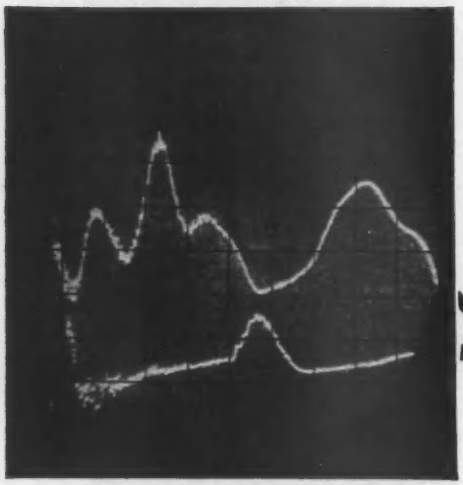
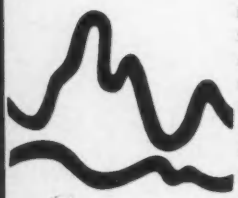
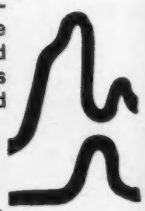
TWO POPULAR PHOTO-RECORDING MATERIALS







You want clear records, so you use a photographic emulsion particularly sensitive to the colour of the trace. And you want a practical combination of emulsion speed and colour sensitivity. Kodak make a wide range of materials for photo-recording so you can have what you want. Here are details of two of them.

R.20 MEDIUM-SPEED BLUE-SENSITIVE FILM

For use in instruments having slow-moving light spots, and for cathode-ray oscilloscope recording with blue screens. It has very high contrast and resolution. Sensitive to all sources except those with mainly green and red emission.

R.60 HIGH-SPEED PANCHROMATIC RECORDING FILM

Recommended for recording work which involves the highest speeds, especially where screens are used with very high writing speeds. Sensitive to ultra-violet and to the visible spectrum.

Kodak

'Kodak' is a registered trade-mark

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Electrically Operated

COUNTER

AT NEW LOW COST

* Rated speed-up to 1000 Counts per minute
* Designed for panel or base mounting
* Centre reset by knob
* Connection by flying leads
* Maximum voltage 110 D.C.—250 A.C.

MODEL 442

English Numbering Machines Limited
Dept. 2K · QUEENSWAY · ENFIELD · MIDDLESEX
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Full technical information on request

LEADING MANUFACTURERS OF COUNTING AND NUMBERING DEVICES

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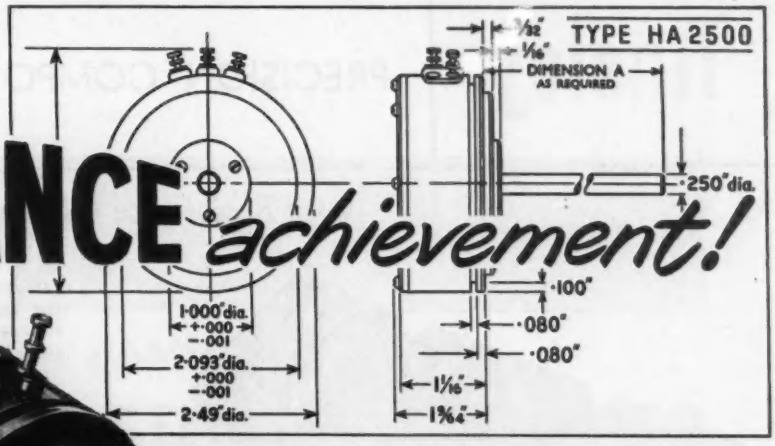
a new RELIANCE achievement!



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HIGH LAW ACCURACY
without cam correction

In this new continuous rotation type HA 2500 Potentiometer intensive research has made possible high accuracy with much improved mechanical stability. A precision machined light alloy body, an accurately ground ball-bearing mounted spindle – a patented design that eliminates cam correction, combine to give the following advantages :—

- LOWER TORQUE
- LONGER LIFE
- REDUCED WEAR
- LOWER COST

BRIEF SPECIFICATION

Resistance range	100 to 100,000 ohms.
Law Accuracy (Absolute)	± 0.25% or ± 0.10%
(Independent law accuracy to closer limits)	
Maximum Starting Torque	1 oz/in.
Maximum Ganged Sections	Four.
Maximum Tappings	Nine.

Full technical details and dimensional drawings in Data Sheet No. 100 available on request.

●

If our standard types do not meet your particular requirements, our research and development engineers are at your service.

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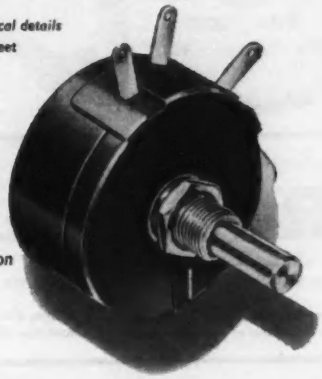
. . . *and* ANOTHER ADDITION TO THE COMPREHENSIVE RELIANCE RANGE

The **TYPE W3** (3 WATT)

This model conforms with specification DEF-5121 style RVW 7 & 8 (formerly RAC.RAD) and is a fully sealed unit with integrally constructed moulded cover. Also available in unsealed version.

Full technical details in Data Sheet No. 9



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GD.60

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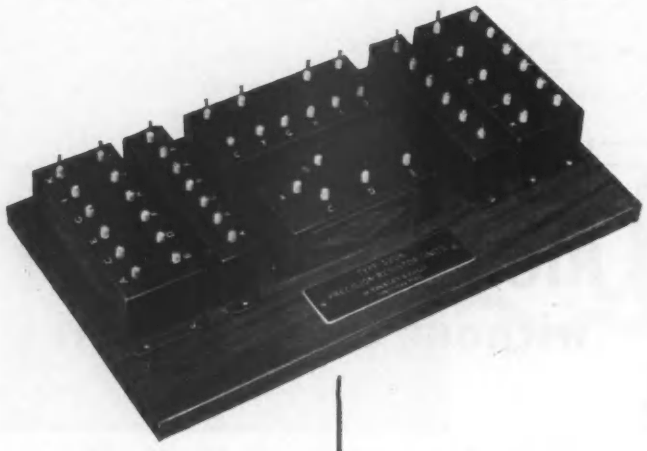
Tinsley

PRECISION COMPONENT RESISTORS

with Resistance tolerance better than 0.1%



Exceptionally compact and light in weight the Type 5206 resistor units of *very high stability* are hermetically sealed in metal cases. Designed for use where resistances up to 10 MΩ are required, the units meet the specifications laid down in R.A.E. Spec. G.1177 and satisfy the tests described in Spec. R.C.S. 11.

Rating: 500 V per MΩ
Temperature coefficient : ± 20 parts per million per °C at room temperature

Time constant: Approximately 10^{-6} seconds
Max voltage: 500 V d.c.

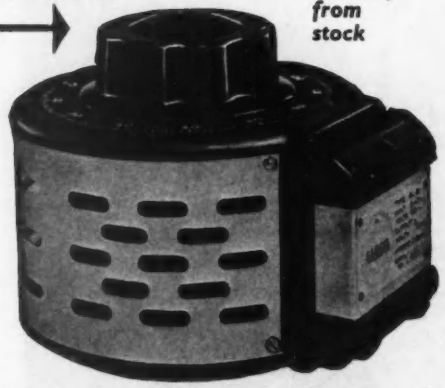
Write for full details to:

H. TINSLEY & CO. LTD. Werndee Hall, South Norwood, London, S.E.25 tel : Addiscombe 6046-8

TY 2

A UNIVERSAL A.C. VOLTAGE & CURRENT CONTROL
. . . with universal fixing centres

Delivery from stock



For the most up-to-date variable transformers . . . for early delivery, too, the obvious choice is the Berco Rotary Regavolt, model 42A, rated at 580 V.A. With a maximum input voltage of 250 V. it will supply a variable output from 0-270 V. Moderately priced at £7.0.9*d.* (skeleton type) and £8.5.11*d.* (protected type as illustrated) the Berco Rotary Regavolt represents the finest value today at the lowest cost.

- **CONSTRUCTION:** Toroidally wound auto-transformers, with tracks formed on one face of the windings.
- **CORE:** Wound from a continuous strip of low loss electrical steel in a similar manner to the well-known C core construction.
- **INSULATION:** Specially processed plastic mouldings ensure minimum shrinkage due to heat and continuous use, and prevent any possibility of the turns slackening.
- **WINDING:** Of high conductivity copper, insulated with a synthetic enamel of the polyvinal acetal-phenal formaldehyde resin type, giving good space factor, exceptionally high abrasion resistance and prolonged heating resistance.
- **FRAME:** Of die cast aluminium, incorporating long spindle bearings and mounting feet to ensure accuracy and rigidity of the mechanism in relation to the fixing holes.
- **BRUSHES:** The brushes are of a special carbon for its contact resistance characteristics, shaped to give minimum loss, maximum strength and longest life.

BRI341-BXH

BERCO

Write for list 615A giving full technical details of this and other models in the Rotary Regavolt range.

THE BRITISH ELECTRIC RESISTANCE CO. LTD.,
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Specialists in the control of current and voltage for more than 25 years

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for industry

Engineering and other industrial firms are offered the following, as one aspect of ROCOL *service.*

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Carter Hydraulic Variable Speed Gears

Smooth stepless speed variation from input speed down to zero r.p.m. with accurate control by Handwheel, Remote Electrical or Lever arrangements.

Carter Variable Speed Gears may be used to pick up loads from zero r.p.m. and speed control setting may be adjusted with the drive running or stationary.

Manufactured in ten sizes for fractional up to 40 horsepower drives.

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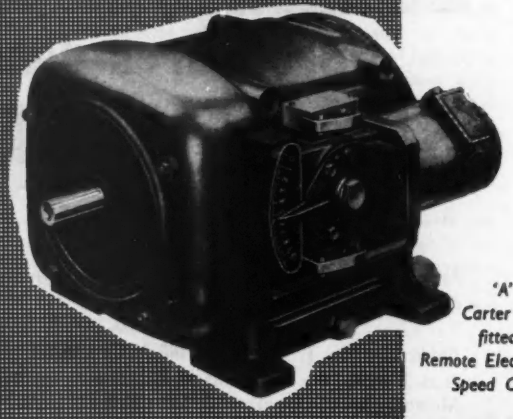

'A' Type Carter Gear fitted with Remote Electrical Speed Control

Carter Gears Limited BRADFORD 3 YORKSHIRE ENGLAND

FLAMEPROOF PRESSURE SWITCH

Designed to meet the requirements of BSS 299 for operation in hazardous atmospheres, and incorporates a stainless steel pressure element. Fully approved by the Ministry of Fuel and Power for Group 1, also 2 and 3 gases.

Pressure ranges for Type SP-1027 from 0-20 p.s.i. to maximum 300 p.s.i. Other Buxton Certified Flameproof Pressure Switches available for ranges 30" w.g. to 5,000 p.s.i. and 0-30" Hg. vacuum.

FULL DETAILS AND SPECIFICATIONS OF THE COMPLETE K.D.G. RANGE ARE READILY AVAILABLE FROM :

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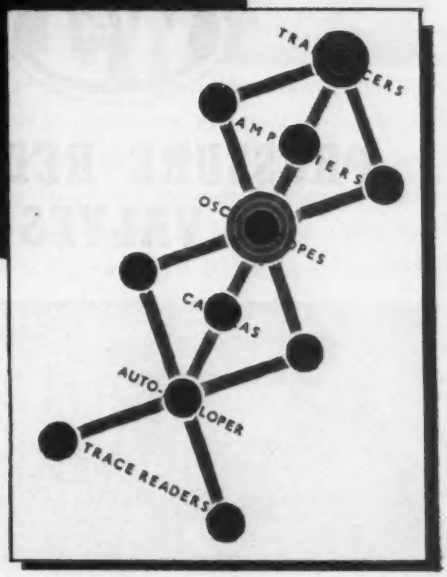
E6Q D.C. Pre-Amplifier

Are your strains determined?

Using bonded or unbonded strain gauges, this unit, part of our modular system, is offered in self contained form.

It consists of a Drift Corrected D.C. Pre-Amplifier and Bridge Panel, this unit offers Flat Frequency Responses to 20 Kcs., Amplification Factors of ·50, 50 and 10, and employs gauges having a resistance upwards of 1000 ohms connected singly, paired or as four arm bridges.



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SOUTHERN INSTRUMENTS LIMITED CAMBERLEY SURREY

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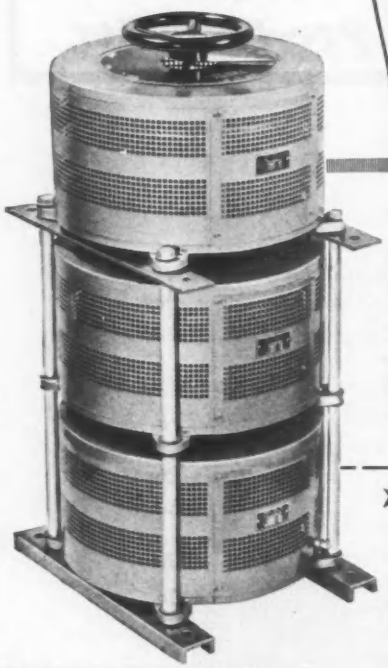
Variac WITH Duratrak ☆

Regd. Trademark

THE MOST USEFUL DEVICE KNOWN FOR THE CONTROL OF AC VOLTAGE



This 3-gang assembly, Type 50-BMG3, will control 22·5kVA, 3-phase or single-phase according to connection. Larger assemblies can be made.

VARIAC is the original continuously-adjustable auto-transformer, providing a smoothly variable output from zero to line voltage and above.

VARIACS are available in a very wide range of models from small units for laboratory and instrument use to large ganged assemblies for three-phase power.

VARIACS are available open or covered, as single units or ganged assemblies, for manual operation or motor-driven.

☆ Duratrak? Duratrak (Regd. Trademark) — a patented* feature exclusive to Variac — is a special plated contact surface giving longer life, increased overload and surge capacity and maximum economy in maintenance. Duratrak is now standard on all models except Series 50.

*U.K. Pat. No. 693406

ONLY VARIAC HAS DURATRAK

This small Variac, Type V-5HMTF, provides an output of 0-270 V, 2 A, from 240 V 50 c/s mains. A still smaller model, Type V-3H is rated at 1 A.

The range includes portable, metalclad and oil-immersed models, dual-output types, high-frequency types and many 'specials'. *Write for complete information.*

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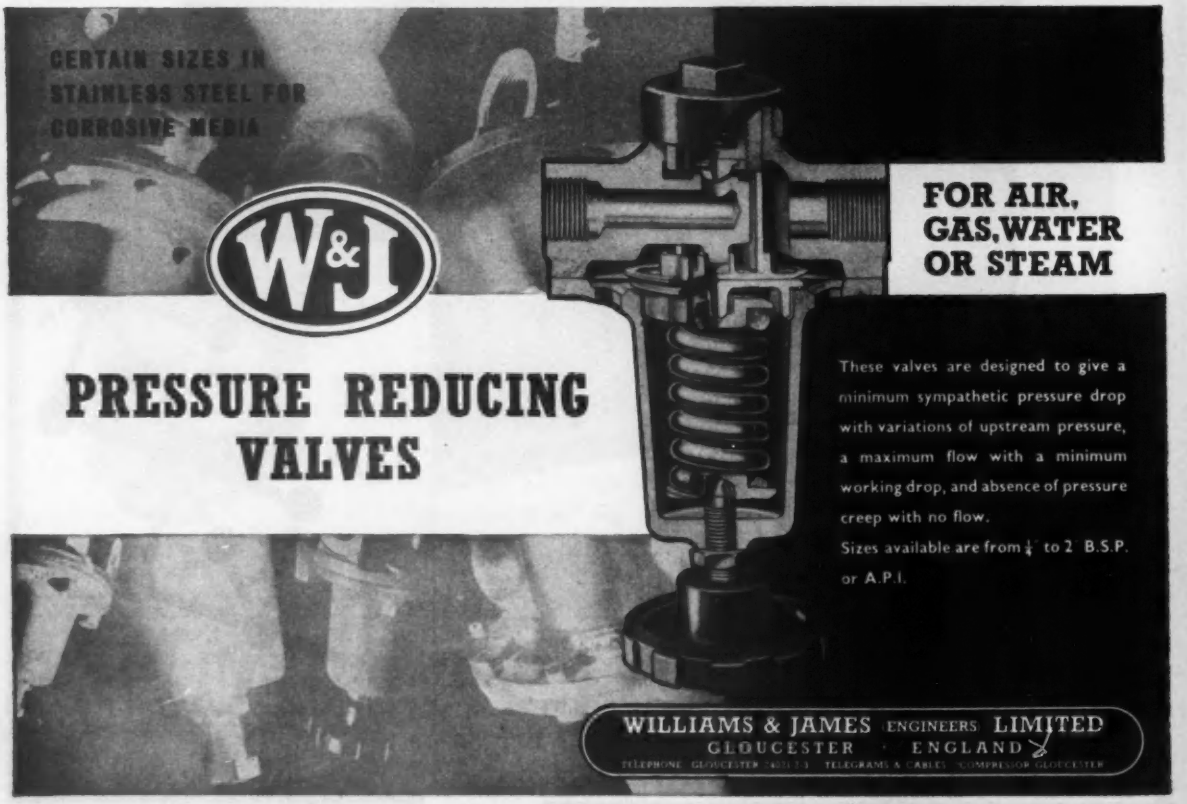
CL 59/xx


CERTAIN SIZES IN STAINLESS STEEL FOR CORROSIVE MEDIA
W&J
PRESSURE REDUCING VALVES
FOR AIR, GAS, WATER OR STEAM
These valves are designed to give a minimum sympathetic pressure drop with variations of upstream pressure, a maximum flow with a minimum working drop, and absence of pressure creep with no flow.
Sizes available are from ¼" to 2 B.S.P. or A.P.I.
WILLIAMS & JAMES ENGINEERS LIMITED
GLOUCESTER ENGLAND

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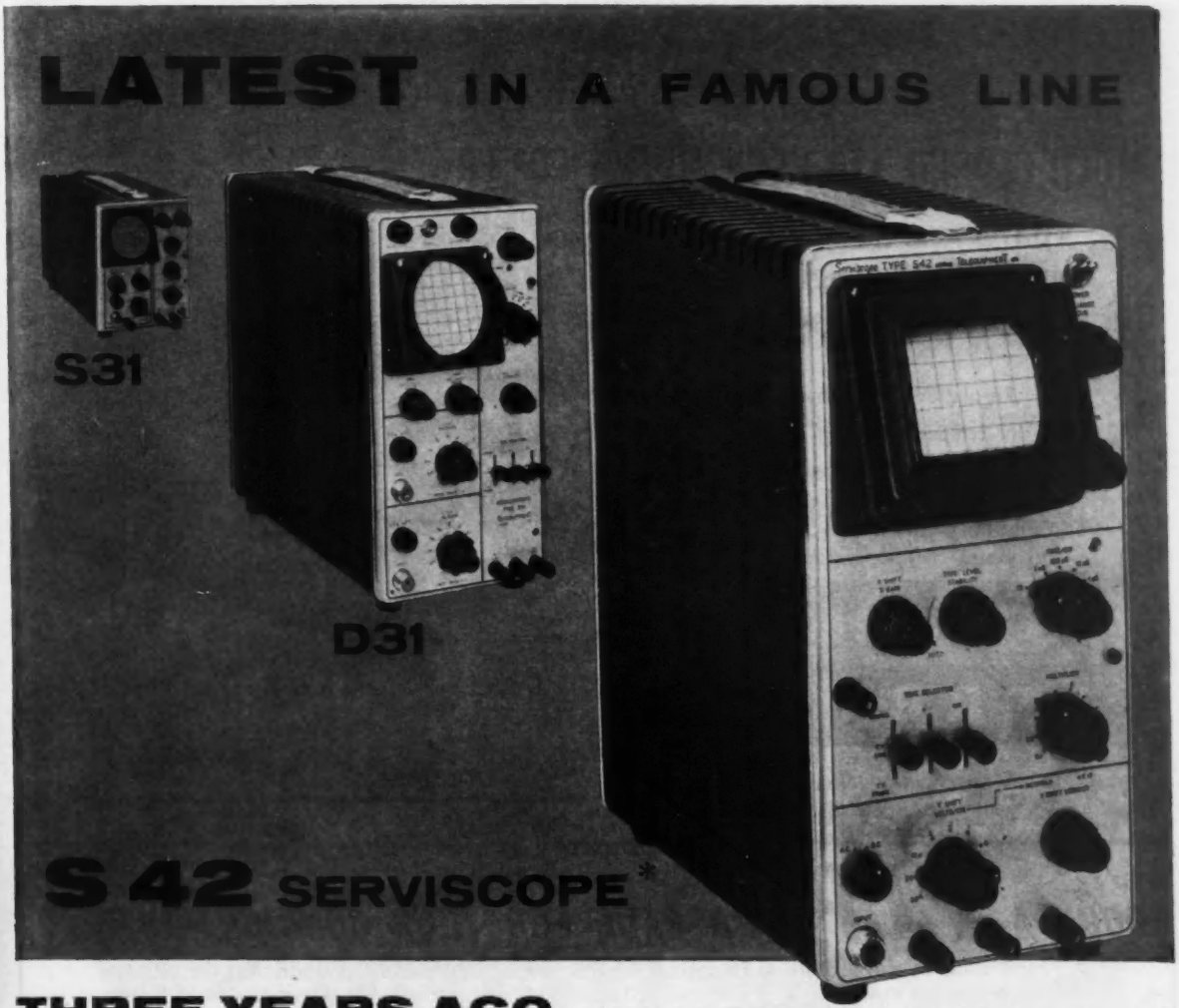

THREE YEARS AGO we offered the first SERVISCOPE* to industry with notable success. Last year we introduced a double beam version and again acceptance was immediate. Now we extend the range still further with the new S.42, a high performance version of the original Serviscope with many outstanding features.

- 4″ spiral P.D.A. C.R. tube operating at 3.7 Kv.
- Increase gain—maximum sensitivity 10 mV.
- Unique extendible light hood.
- Pulse bright-up for single stroke working.
- H.F. synchronisation compatible with Y amplifier performance.

Accurate calibrated input attenuator. Wide range calibrated time base (down to 5 sec/cm. if necessary). X expansion control to 10 dia. D.C. coupled flyback banking. Versatile triggering circuit unique to 'Serviscopes'. Illuminated graticule. Weight: 18 lbs. Price: £92.

Basically the same rugged, lightweight, versatile instrument as its well-tried predecessors, the S.42 has the ability to meet more exacting demands with its high writing speed and additional high gain facility. Evolved originally for computer development and servicing, the S.42 has special applications wherever pulses have to be measured at low repetition rates, for example, a single shot 1μ sec. pulse can be seen and photographed. In addition, it has general applications throughout the electronics industry.

TELEQUIPMENT

'Serviscope' is the registered trade mark of TELEQUIPMENT LIMITED 313 Chase Road, Southgate, London, N.14. *Tel.: Fox Lane 1166*

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MUCH CLOSER VOLTAGE ±½% CONTROL

with
Carbon Pile Wattages and
Transistorised Sensitivity

Regulation closer than ± ½% between extremes of temperature from —60°c to +70°c. Speed of response 50/60 milliseconds.
Dimensions 5" x 6" x 5½" high Weight 4 lb.

Model shown is for the control of a 28 volt D.C. generator for use on aircraft.

NEWTON DERBY

NEWTON BROS. (DERBY) LIMITED
ALFRETON ROAD DERBY

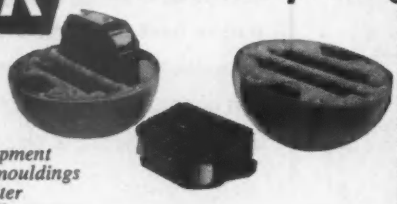
Telephone : Derby 47676 (4 lines) *Grams : DYNAMO, DERBY*
London Office : *IMPERIAL BUILDINGS,* *56 KINGSWAY W.C.2.*

BOOK A V.I.P. PASSAGE FOR YOUR CONSIGNMENT . . .

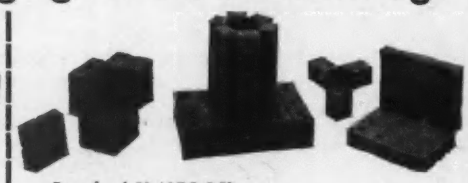
. . . send it on its way, secure in its special Hairlok tailor-made packaging. Hairlok is the ultimate answer to damage in transit. It is compounded from the finest curled animal hair coated with latex rubber and completely bonded into place to absorb every impact, shock or vibration. The Hairlok Laboratories comprise a team of specialists fully versed in the designing, testing, and constructing of packaging to the most stringent requirements to assure safe transit of the most delicate equipment.

- ATLAS—The HAIRLOK Modulator System for Packaging—provides the answer to standardisation as well as protection.
- HAIRLOK is made in many densities—to absorb a variety of shocks, protect different weights.
- HARLOK Laboratories design complete packages for special items, including individual outers for specific transport/handling problems.

Hairlok -scientific packaging for the scientific age



Vital items of electronic equipment with their own HAIRLOK mouldings and a special self-righting outer case developed by HAIRLOK Laboratories.

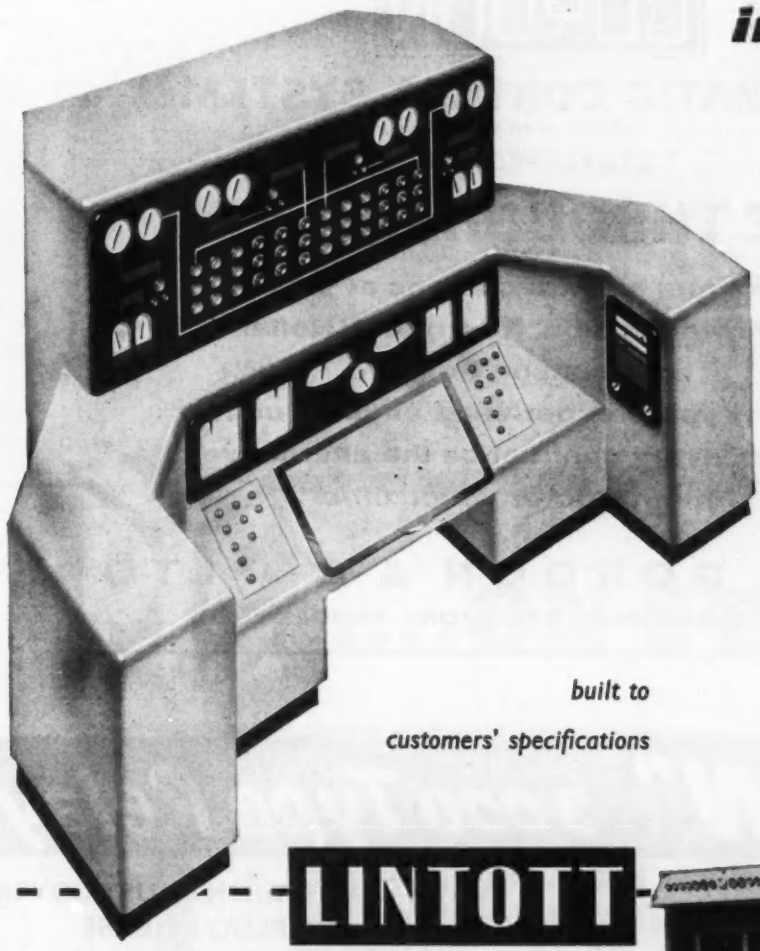


Standard HAIRLOK mouldings from the Atlas System range. These can be built up to protect many different shapes and sizes.

For literature and further details, write or phone :

THE HAIRLOK COMPANY LTD., Magna Works, Kathie Road, Bedford. Tel. Bedford 4271

* the case for perfect housing in electronics



built to customers' specifications

FOR CONTROL

Desks and Panels

Lintott fabrication serves the electronic and nucleonic industries with Control Desks and Panels that enhance the operating scheme. Working in close collaboration with designers, Lintott produce units for all forms of process control, burner control, nuclear control, etc. This includes sheet metal work, surface finishing, flow diagram mounting and installation of instruments and switchgear. Perfect housing helps to sell your equipment. Let Lintott quote for construction on your next project.

LINTOTT

FOR EQUIPMENT...

a flexible system of cabinets

Lin-cabinets provide a standard and yet completely flexible system for housing electronic and electro-mechanical equipment. They are designed to accommodate any arrangement of components and any combination of chassis. Each unit is self-contained, with built-in cooling or heating facilities, and are suitable for slight pressurisation. The three standard drawers of 8″, 12″ and 16″ can be used in any combination to give a total height of 52″ and any number of cabinets can be interlinked. Lin-cabinets are K114 approved for the three Services and lend themselves to many applications. Plan your equipment layout with Lin-cabinets in mind and enjoy low installation costs, low maintenance costs, with maximum efficiency.

Data Sheet LC. No. 1.

AYLING INDUSTRIES GROUP

H. & E. LINTOTT LTD., Horsham, Sussex. *Telephone:* Horsham 3316 Telex 8746

Circle No 119 on reply card for further details

THE

GORDON

AUTOMATIC CONTROL SYSTEM

(PATENT APPLIED FOR)

DEVELOPED FOR

ONCE THROUGH BOILERS

Has met all expectations at the
Maas Power Station, Roermond, Holland
on a Benson Boiler
Our thirty years experience enables us to
offer with every confidence the alternative
Pneumatic or Electronic

JAMES GORDON & CO. LTD

DALSTON GARDENS, STANMORE, MIDDLESEX

"PLUG-IN" 3,000 Type Relay

NOW SUPPLIED AS FOLLOWS:

- 6 Change-overs Light Duty
- 6 Makes or 6 Breaks Heavy Duty
- 2 Change-overs Heavy Duty and 2 Change-overs Light Duty
- Transistorised to operate as low as 3 micro-amps
- A.C. Operation for: 6v. 12v. 50v. 110v. and 250v. A.C.
- Double Wound Coils
- P.T.F.E. Insulation
- Operate and Delay up to 5 Seconds.

A.I.D. A.R.B.
ADMIRALTY APPROVED
3000 & 600 TYPE RELAYS

SIZE OF BASE
$2\frac{3}{4}'' \times 1\frac{1}{4}'' \times \frac{1}{2}''$

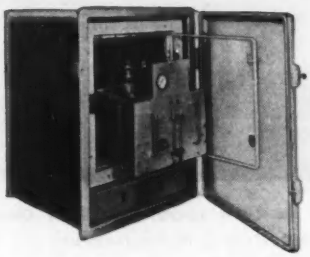
WITH TRANSPARENT DUST COVER
AND PLUG-IN BASE

As supplied exclusively for

BERKELEY
POWER STATION

A.D.S. RELAYS LTD 89-97, ST. JOHN STREET, CLERKENWELL, E.C.1.
Telephone: CLErkenwell 3393/4/5.

Process Analyser



The Pye Process Analyser is an industrial version of the well-known Pye Argon Chromatograph. By utilising an argon ionisation detector instead of a katharometer or thermistors, it achieves an outstanding performance with high sensitivity and exceptional stability. Its comparatively simple and robust design results in reliability, ease of operation and low overall cost.

The instrument draws a sample from the process stream, analyses it and presents the results on a recorder. A versatile control system selects and attenuates a number of individual peaks or gives a complete chromatogram.

The equipment, which is suitable for use in hazardous locations, is completely flexible in application. Facilities which may be supplied for individual installations include dual column analysis, multi-stream analysis, column switching, flow programming and others.

PYE ....ON STREAM!

APPLICATIONS

- ★ **PERCENTAGE ANALYSIS** of mixed hydrocarbons.
- ★ **TRACE IMPURITIES** in air, oxygen or industrial gases.
- ★ **MONITORING OF CRITICAL COMPONENTS** in a process stream.

PYE FEATURES

- ★ CONTINUOUS AUTOMATIC ANALYSIS requiring no supervision.
- ★ ULTRA-HIGH SENSITIVITIES for analysis in p.p.m. range.
- ★ CONVENTIONAL SENSITIVITIES for analysis in % range.
- ★ VERSATILITY in a wide range of applications.
- ★ COMPREHENSIVE ANALYSIS FOR LESS OUTLAY in comparison with other methods.
- ★ AIR PURGED for use in hazardous locations.
- ★ BRITISH DESIGN AND BRITISH MANUFACTURE THROUGHOUT.

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Granta Works, P.O. Box 80, Cambridge, England
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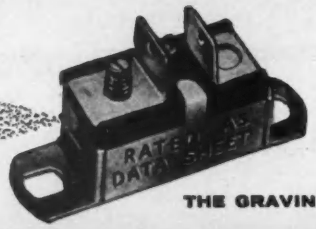
SCIENTIFIC PYE INSTRUMENTS

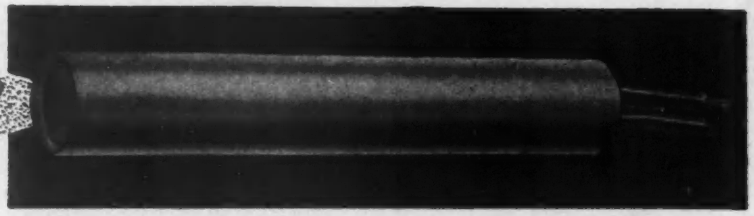
Circle No 121 on reply card for further details

Pin-point Automatic Accuracy



THE GRAVINETTE

Write for Catalogue G. 100 Temperature Control Switches



THE GRAVINETTE

A miniature precision unit for Surface Mounting, to provide for optimum temperature control on applications where space is at a premium. The Gravinette is an adjustable unit and is offered in four versions :—

Type TCS 3150, normally closed, range—70°C to 100°C,
Type TCS 3151, normally open, range—70°C to 100°C,
Type TCS 3250, normally closed, range 40°C to 250°C,
Type TCS 3251, normally open, range 40°C to 250°C.

Normal rating 1 amp. on 250v A.C., and 2 amps on 28v D.C.

CARTRIDGE TYPE SERIES 1000, TENSION OPERATED

These precision temperature control switches are designed primarily for use in heater blocks, heated plates and similar applications where excessive moisture or vapour is not present. Possessing the desirable features of the ideal thermostat, the Graviner Temperature Control Switch is of convenient size and shape, adjustable and resistant to vibration and shock, and easy to install.

Current Rating 5 amps 250v. A.C. for standard types.

T TEMPERATURE
C CONTROL
S SWITCHES

For further details of our complete range write or telephone

GRAVINER, 10 CHURCH ST., STAINES, MIDDLESEX
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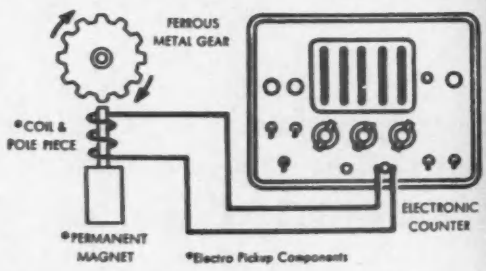
Specialists in Airborne and Industrial Fire and Explosion Protection, Nuclear Development and Production Engineering



Electro

MAGNETIC TRANSDUCERS

SUB-MINIATURE 3055

Actuates. Provides Telemetering Data. Indicates. Controls. Synchronizes.

ACTUAL SIZE

A precise way to solve your speed measurement problems

Here's how to measure turbine speeds up to 100,000 rpm...

a. Mount Magnetic Pickup near teeth of any convenient gear in the machine—or add a small bit of magnetic material to a non-magnetic rotor.

b. Connect Magnetic Pickup directly to electronic counter. Set counter to count for a suitable time—such as 1 second (1/60 minute).

Example: 60-tooth gear providing 60 pulses/revolution with a count of 1 sec. (1/60 min.) will produce an accuracy of ± 1 rpm at any speed. (Counter reads rpm directly with this set-up.) If counting time is increased to 10 sec., accuracy will be ± 1/10 rpm.

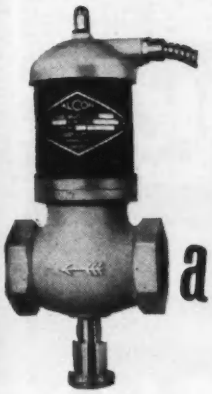
Write for Specification 58.084

ELECTRO PRODUCTS LABORATORIES INC. CHICAGO.

Makers of Precision Electronic Instruments

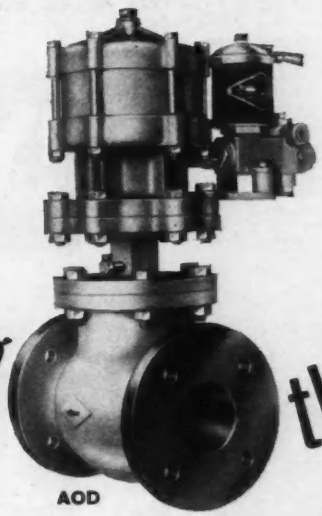
United Kingdom Representative . . .

A. J. CARRICK SMITH (LONDON) LTD.
45 Ladbroke Square London W.11
Telephone PARK 5313

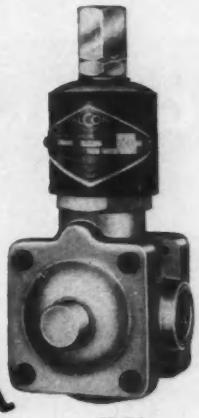


ACH

anything that flows



AOD



SPC 3

ACO

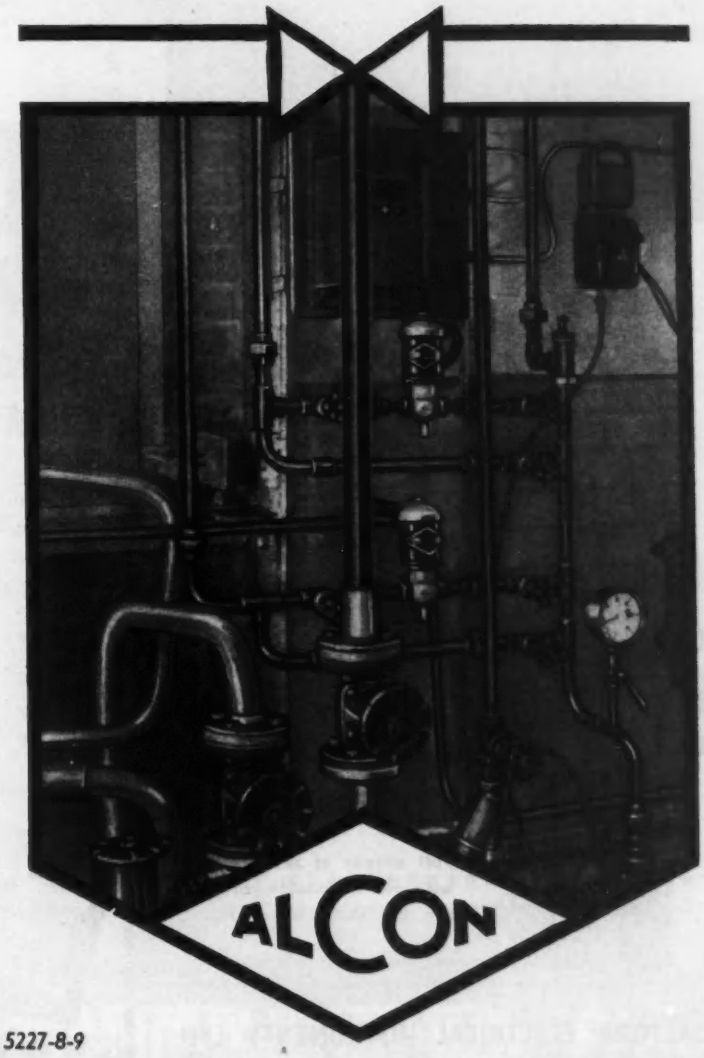
All Liquids and Gases can be positively controlled by an Alcon Solenoid or Air-Operated Valve. Sizes from $\frac{1}{8}$" B.S.P. to 8" Bore. Pressures up to 1,500 p.s.i. Temperatures up to 300°C. Body materials to suit all media including corrosive acids, with Standard, Weatherproof or Buxton Certified Flameproof Solenoid Housings. Glandless, Fluon Glands or Stainless Steel Bellows Glands.

AIR-OPERATED Type AOD —Heavy duty air operated units individually designed for control applications beyond capabilities of Solenoid types. For pressures up to 1,500 p.s.i. Sizes $\frac{1}{2}$" B.S.P.—8" Bore.

SPC.3—Three-way valves for electro-pneumatic control systems. Sizes up to $\frac{1}{2}$" B.S.P. for use with air up to 150 p.s.i.

MIDGET Type ACO—Sizes up to $\frac{1}{2}$" B.S.P., used for control of air, gases, water, oil at pressures up to 300 p.s.i. Single way—Reverse acting—Three-way types available.

ACH—Hand Reset type, closing automatically on current failure, for low and medium pressures. Sizes from $\frac{1}{4}$" B.S.P. to 6" Bore. Inexpensive, simple construction, reliable in operation. Also available type ACHL. Lever operated for use with steam, hot water and pre-heated fuel oils.



'Phone : SUTton Coldfield 5227-8-9

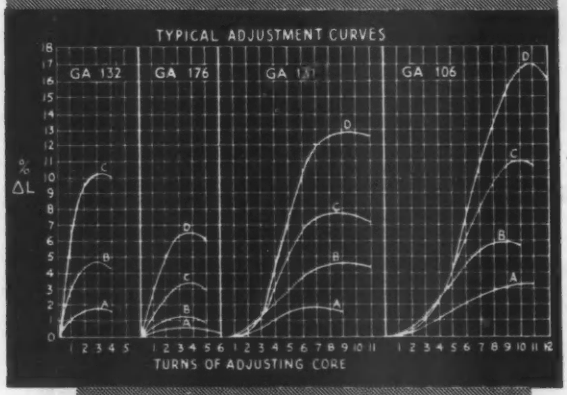
ALEXANDER CONTROLS LTD., REDDICAP HILL, SUTTON COLDFIELD, WARWICKSHIRE

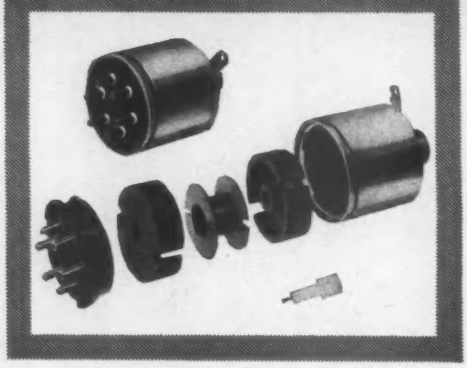
A MEMBER OF THE CONCENTRIC GROUP OF COMPANIES

Gecolite

ASSEMBLIES

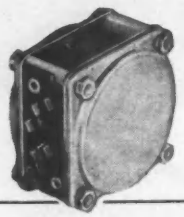
Adjustable Ferrite Cores





In Grade P. Gecolite, nominal initial Permeability 1200/1880.

Write for Data Sheet 592



Full details of assemblies with non adjustable cores, ask for Data Sheet 591.

SALFORD ELECTRICAL INSTRUMENTS LTD

TIMES MILL · HEYWOOD · LANCASHIRE · Tel: HEYWOOD 6868
London Sales Office: Magnet House, Kingsway, W.C.2. *Tel:* Temple Bar 4668
A Subsidiary of THE GENERAL ELECTRICAL CO. LTD. OF ENGLAND

SLYDLOK

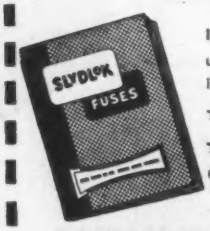
SLYDLOK

SLYDLOK

THE 'SLIDE AND LOCK' VIBRATION-PROOF FUSEGEAR

As with the name, so with the fuse, slide the top into position and there you have the anti-vibration lock which has been the feature distinguishing SLYDLOK fuses the world over.

- *Moulded in black plastic.*
- *Rewireable and H.R.C. types for 250V. and 440V. use.*
- *Patterns for surface and inset mounting, and a quite incredible variety of methods for connecting base cables.*



In case you haven't heard, the latest "H" units are also offered complete with inbuilt neon indicator lamps.

These you must see!!

They are all in the book, the Slydlok Fuse Catalogue, send for your copy now.

EDWARD WILCOX
AND COMPANY LIMITED
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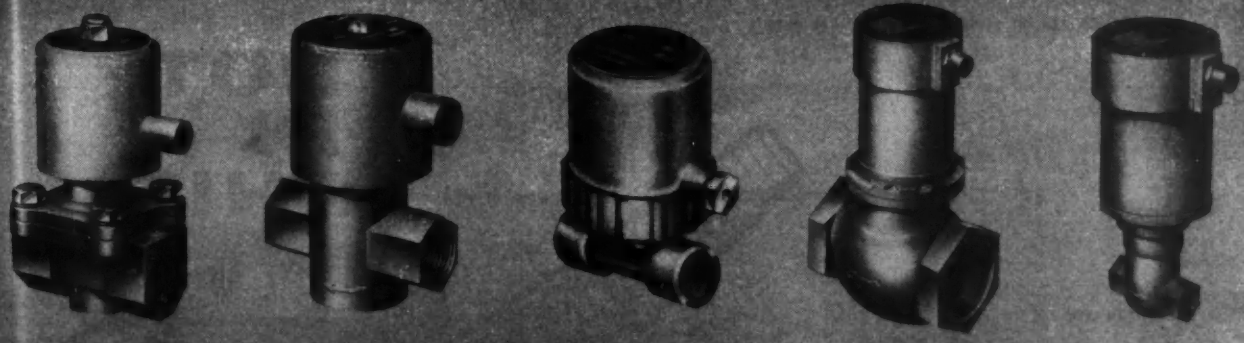
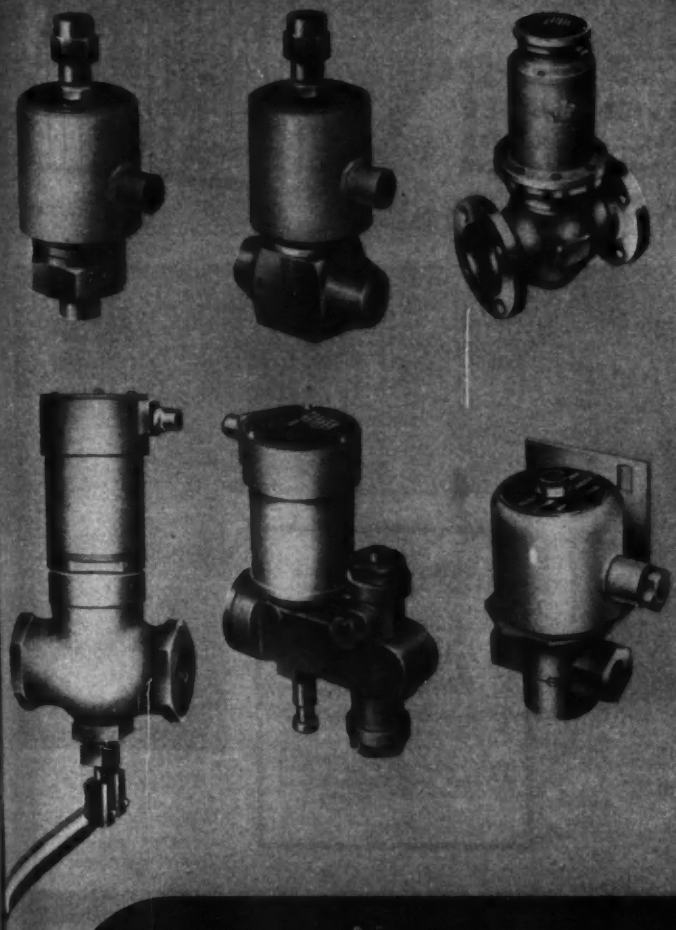
EW.3

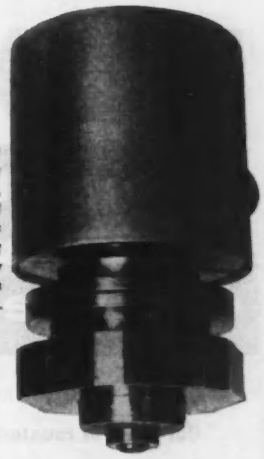


For any type of SOLENOID VALVE
—whatever your need



SPECIALS made to suit customers' requirements

If the solenoid valves you require are not included in our comprehensive standard ranges, our Design Engineers will gladly develop special types to suit your requirements. Whatever your need, send us your enquiries for prompt attention.



Custom-built for a Swedish atomic energy application, this stainless-steel solenoid valve is used for controlling radio-active heavy water at temperatures up to 250°C.

contact ETHER *first!*
LIMITED

ETHER LTD., *Combustion Safeguard and Solenoid Valve Division,*
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NOT IN THIS CASE!

There are many ways of packing sensitive engineering items, from radio valves to large engineering assemblies; but there is only one satisfactory method—scientific packing by EXPORT PACKING SERVICE. EPS ensure safe storage and safe arrival, thus reducing customer complaints and cutting costs.

LET EPS SCIENTIFICALLY SOLVE YOUR PACKING PROBLEMS

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Works at Sittingbourne and Chipping Warden nr. Banbury

AP65

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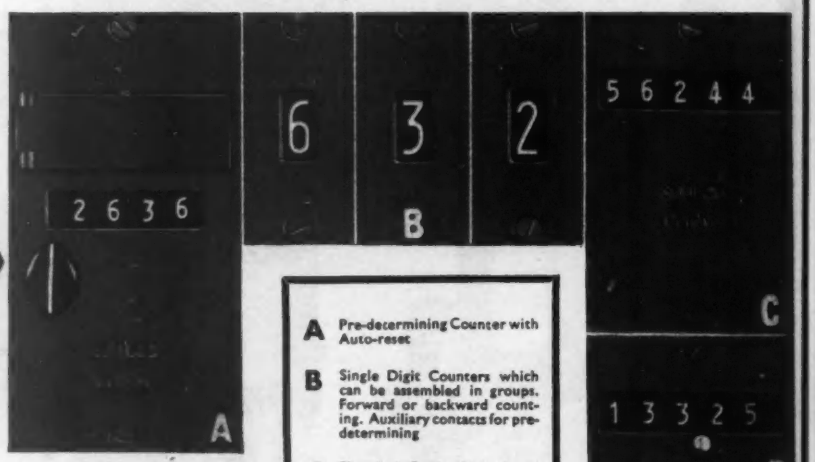
small impulse counters



A Pre-determining Counter with Auto-reset

B Single Digit Counters which can be assembled in groups. Forward or backward counting. Auxiliary contacts for pre-determining

C Electrical Reset High Speed Counters

D Instantaneous Manual Reset High Speed Counters (10 or 25 impulses per second)

Our range of counters offers in the most compact form types for all requirements. The total full size width of the group above is only 6 inches.

Send for full details of the above and other counters in our range to

THE STONEBRIDGE ELECTRICAL CO. LTD.
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CONTROLS & INSTRUMENTS
STONEBRIDGE

Agents and Licensees in U.K. for "SODECO", GENEVA.

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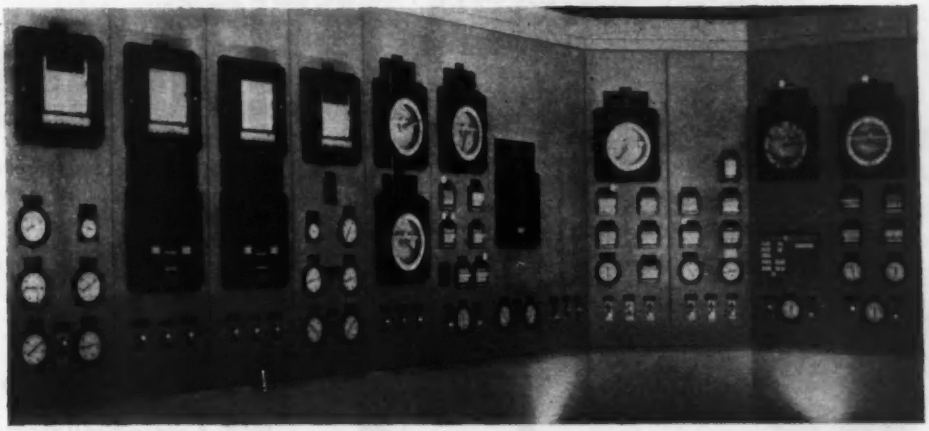

Speedomax

Instrument Installation controlling Olefine production

at

I.C.I.

WE are indebted to Imperial Chemical Industries Limited for the above photograph of a small part of the Speedomax instrument installation controlling olefine production.

THIS special installation, of course, involved considerable consultation and collaboration between I.C.I. Instrument Engineers and our Research Staff. No matter how simple or complex your problem, we will be glad to hear from you and to give you any assistance in our power.

INTEGRA, LEEDS
183 Broad Street

Phone: Midland 1453/5

& NORTHRUP LTD.
Birmingham 15

Telegrams: Flometer, Birmingham

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Measure Relative Humidity in Seconds

WITH THE BATTERY ★OPERATED

Hygrophil

This unique psychrometer employs a minute germanium based thermo-sensitive element which gives accurate and consistent results to 0·5%. Lightweight and portable, the fast response of the HYGROPHIL enables rapid cross sectional valuations of entire rooms.

Three scale ranges are incorporated, covering temperatures from + 10 to + 176°F. A conventional curve diagram delivered with the unit permits immediate interpolation of readings.

★ *A clockwork driven unit is available for use where flameproof equipment is desirable.*

Full information sent on request

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Nylon COIL BOBBINS

FOR MINIATURE TRANSFORMERS

Ever thought about GG MINICASTS in Zinc Alloy?

There's nothing to touch GG MiniCasts for tiny metal parts — *cost less* because all machining, assembly, welding, scrap and tool costs are either reduced or eliminated. Send for free details today!

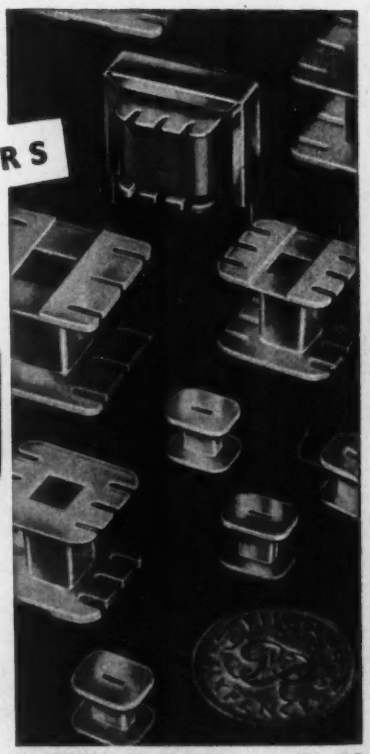
Write for fully explanatory literature

GG MINIMOULDINGS IN NYLON

SAVE UP TO HALF YOUR COSTS!

CUT WINDING AND HANDLING COSTS
PRECISION ACCURACY · UNIFORM QUALITY
GREATER DIELECTRIC STRENGTH
ONE-PIECE CONSTRUCTION (cannot come apart)
GREATER RIGIDITY

Bobbins to suit square stacks of standard MEA laminations available from stock. Initial range sizes 21 (RCL 421), 187 (RCL 450), 262 (RCL 531) and 218. Others subject to general demand.



Enjoy all these advantages by using GG MiniMouldings for Bearings, Washers, Connectors, Gears, Insulators, Rivets, Screws, Rollers, Valve Seats, etc., etc.

GEORGE GOODMAN LTD

ROBIN HOOD LANE · BIRMINGHAM 28 · *Telephone*: SHIRLEY 4491

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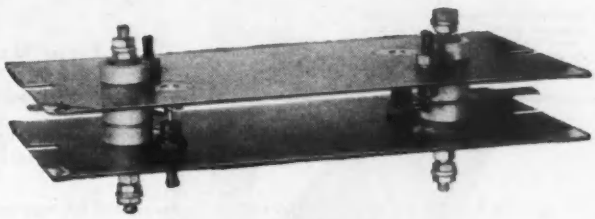
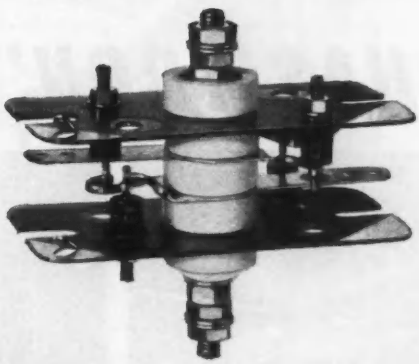
BRADLEY
BRIDGE RECTIFIERS

INCORPORATING LUCAS SILICON DIODES

A new range of silicon rectifiers, suitable for single-phase full-wave bridge operation. Available in 2A, 7A, 12·5A and 20A stacks, each with peak inverse voltage ratings of 50, 100, 200 and 400 volts.





Model No.	Dimensions (inches)	P.I.V.	Max. Input volts (R.M.S.)	† IDC max. (amps.) at 25°C.	Max. Ambient Operating Temp. °C.
IB320A	1½×3×2¾	50	35	2.0	150
IB321A	1½×3×2¾	100	70	2.0	150
IB323A	1½×3×2¾	200	140	2.0	150
IB326A	1½×3×2¾	400	280	2.0	150
IB320B	3 ×6×2¾	50	35	2.0	150
IB321B	3 ×6×2¾	100	70	2.0	150
IB323B	3 ×6×2¾	200	140	2.0	150
IB326B	3 ×6×2¾	400	280	2.0	150
IB510A	1½×3×2¾	50	35	10.0	100
IB511A	1½×3×2¾	100	70	10.0	100
IB513A	1½×3×2¾	200	140	10.0	100
IB516A	1½×3×2¾	400	280	10.0	100
IB510B	3 ×6×2¾	50	35	18.5	100
IB511B	3 ×6×2¾	100	70	18.5	100
IB513B	3 ×6×2¾	200	140	18.5	100
IB516B	3 ×6×2¾	400	280	18.5	100
IB510C	4 ×8×2¾	50	35	20.0	100
IB511C	4 ×8×2¾	100	70	20.0	100
IB513C	4 ×8×2¾	200	140	20.0	100
IB516C	4 ×8×2¾	400	280	20.0	100

Joseph Lucas Ltd

For further information and prices—apply to

G & E Bradley Ltd

SEMI-CONDUCTOR DIVISION. Telephone Gladstone 0012
ELECTRAL HOUSE, NEASDEN LANE, LONDON, N.W.10.
A Subsidiary Company of Joseph Lucas (Industries) Ltd.

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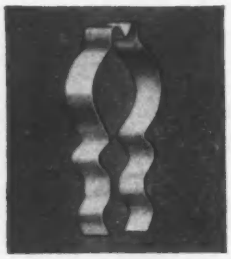
Circle **No 134** on reply card for further details

LS products for the Electronics Industry

(Ex Stock from works or London Office)

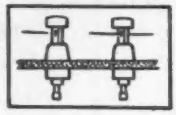


TRANSISTOR CLIPS
in Beryllium Copper

(Patent and Type Approval applied for)

Of compact design, and taking up no more room than the Transistor itself, these Clips, manufactured from Beryllium Copper and formed so as to assist heat dissipation, are designed to suit cylindrical Transistors such as the Mullard OC.72 for fixing horizontally to printed circuit boards.

Top illustration shows the clip greatly enlarged whilst the lower picture shows the clip actual size and also the method of fixing.



Pressure on the terminal cap opens the transverse hole and allows the wire or pin to be inserted. Release pressure and wire or pin is firmly held in position.

SPRING LOADED WIRING TERMINAL

Designed for mounting on panels up to $\frac{1}{8}$" thick, the terminal accepts wire ends or pins up to $\frac{1}{8}$" diameter and provides a quick and simple connection, secure and proof against vibration. Terminals are available from stock with Black or Red Thermo-plastic fittings or other colours to order.

Ratings :—Current 5 amp. Test Voltage 1000 V., with contact resistance. (Patent and Type Approval applied for).

for Reliability . .

LEAVE IT TO **Lewis** OF REDDITCH
SPRINGS, PRESSWORK AND WIRE FORMS TO FINE LIMITS

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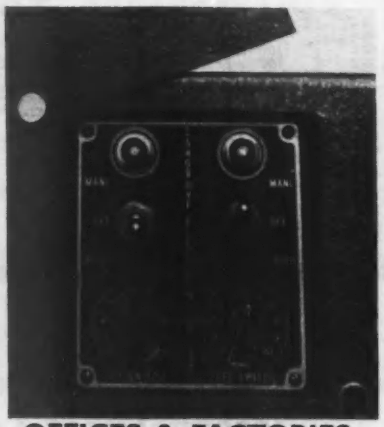
Send 2/6 P.O. for our 40 page booklet on spring design with full technical data. It is an invaluable reference for your design department.

'PHASITRON' Controls Artificial Lighting

IN MODERN STORES

Its Application

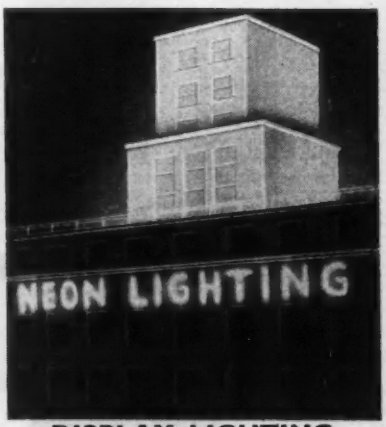
The "PHASITRON" system should be used to control the artificial lighting in all areas where the natural lighting is good in Stores, Warehouses and Factories. Add-on circuit controllers can also be used for flood lighting and advertising signs.



OFFICES & FACTORIES

How it Operates

The strength of the natural light is sensed continuously and the artificial lighting will be turned off automatically when it is not needed in any particular area.
The lighting is restored immediately whenever the daylight is insufficient.



DISPLAY LIGHTING

Considerable Saving outweighs Cost

The savings are threefold:—
1. No light burns wastefully.
2. No bad work results from lack of artificial lighting.
3. "PHASITRON" "Smooth Transition" special circuit arrangement can cut down the lighting bill an hour a day.

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The Illustration shows our P.4 Series arranged for panel and base mounting with machine type handle.

ARROW Rotary Packet switches have, for many years, enjoyed an enviable reputation for excellence of design and fine performance.

Considerable saving in cost can be effected by the simultaneous switching of various circuits using ARROW Rotary switches.

QUICK DELIVERY

Write TODAY for a copy of LIST R.P.2. describing our P.4 Series illustrated here.

P.4 SERIES

Maximum Non-Reactive Ratings

30/35 Amps 250v AC/DC
20/30 Amps 440v AC/DC
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ARROW ELECTRIC SWITCHES LTD
HANGER LANE · LONDON W5

A/31

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Front view. Common to all mocels

These flow indicators (Type 715 series) are versatile units, simple to install and occupying the minimum of panel space, with no awkward front of panel projections.

New flush mounting purge meters

—packaged units with pressure regulators

Type 715 D. Back view

- One hole fixing
- No projections in front of panel
- Needle valve operation by coin slot
- Coin slot discourages unauthorised adjustment
- Self contained units reduce installation costs
- Can be spaced as close as 4″ centres

The series consists of four instruments

Type 715 A ..... Simple indicator
715 B ..... Indicator with needle valve
715 C ..... Indicator, needle valve, and simple pressure regulator
715 D ..... Indicator, needle valve, and differential pressure regulator

ROTAMETER

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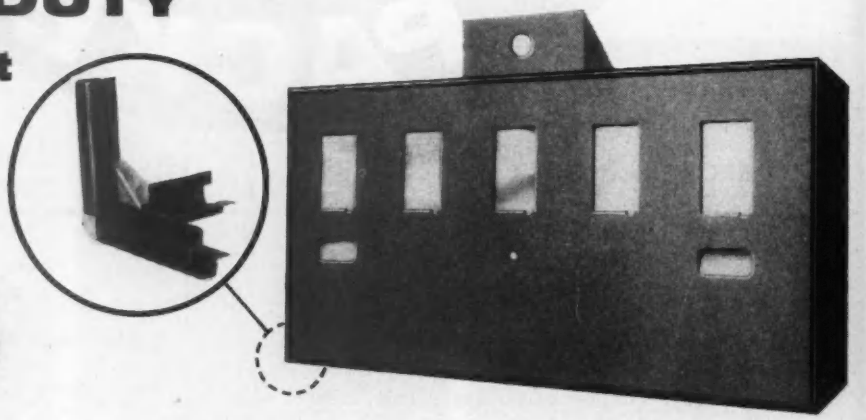
GD320/34

HEAVY DUTY Instrument Racks from LUNDS of Wandsworth



Lunds heavy duty instrumentation racks have been developed to overcome the problems inherent in the construction of larger instrument panels. Corner casting of aluminium alloy, designed to eliminate welding at corners, are incorporated with 10 gauge radius rolled sections in mild steel to form a rack of unique strength. The sections incorporate a ¾″ x ¾″ recess which facilitates flush panel mounting and door fitting.

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Other Lund products include standard racks and panels; and sheet metal work for the electronics industry—comprising specialised racks, consoles, desks, etc., For full details of Lund products write or telephone today.

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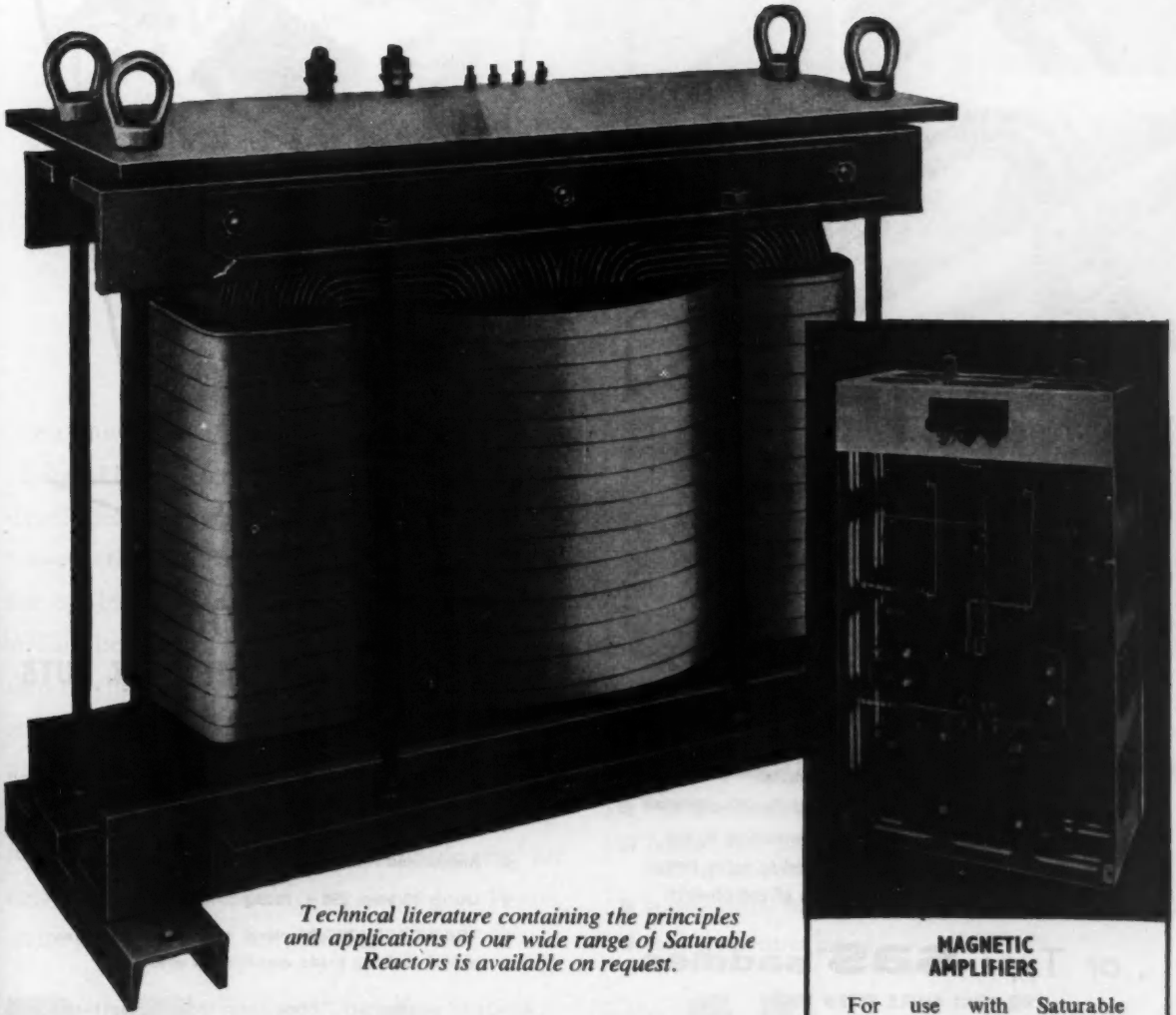
TRANSDUCTORS

Haddon **"STANDARD"** Saturable Reactors—Transductors operate from conventional A.C. line Voltages and provide a choice of D.C. Voltages for Control Windings. Selected from a wide range of individually designed and manufactured **SPECIALS** over past years, the **HADDON STANDARD RANGE** enable the discerning engineer to select **STANDARD EQUIPMENT** for Specific application. 416 standard single-phase designs cover the range 1 kVA to 300 kVA.

They provide the best method of stepless control in both long-term economies and high performance standard.



Technical literature containing the principles and applications of our wide range of Saturable Reactors is available on request.

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For use with Saturable Reactors Haddon manufacture a standard line of Magnetic Amplifiers.

Operating from 200/250V 50/60 c/s single-phase supply, with input of 0–5 mA DC in 2000/8000 ohms.

Illustrated above is the 1000W Magnetic Amplifier

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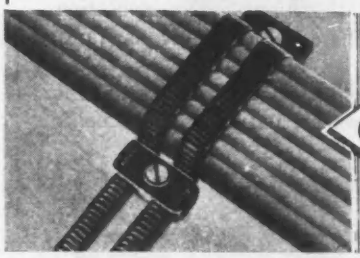
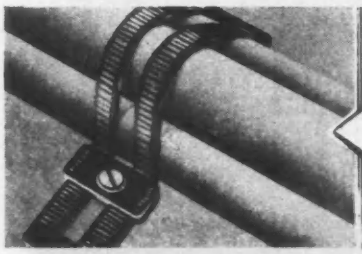
complete cable security—



with increased efficiency and



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Type AS saddles

2 POINT 2 SCREW FIXING

The quickest most convenient, most versatile and economical Cable securing method yet available.
Designed specially for wall and panel mounted wiring installations, the AS Cable Saddle will accommodate cables of any diameter, type or combination, providing complete security with the highest insulation and anti-corrosive qualities in any climatic conditions.
Only 3 sizes are required to cover the most complex cable assembly.

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- ★ Absolutely anti-corrosive
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- ★ No need to carry large stocks of components

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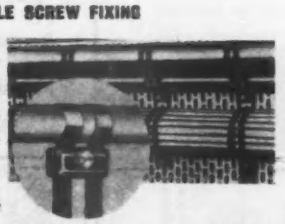

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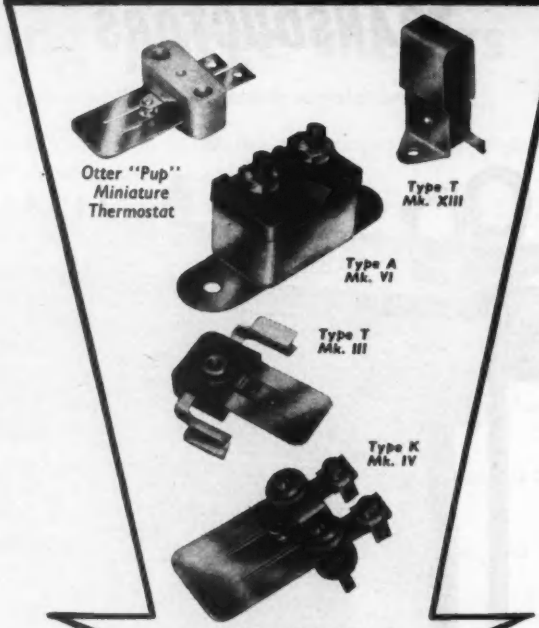
WORLD PATENTS INCLUDING PATENT NUMBERS 600055, 622781, 624905, 657434, 713443, 749716, 774911, 782668 AND OTHERS
ALSO OTHER PATENTS PENDING



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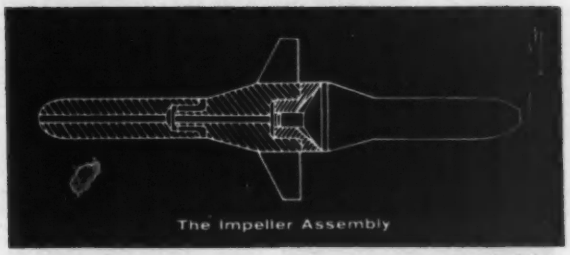
Meterflow Ltd announce an entirely new range of flowmeters and associated equipment developed and made in Great Britain. Unique construction utilises the pressure drop across the blades to hold the impeller off the down-stream bearing. This inherent self-compensation of the down-stream thrust, together with spirally-cut blades, enable these flowmeters to give the highest accuracy at all speeds, reliability, and long life. The Meterflow range is made of stainless steel and suitable for all corrosive and non-corrosive liquids. Please write or 'phone for full details.



The Impeller Assembly

Patent Applied For

- **Repeatability 0·1%, Linearity ± 0·25%.**
- **Low pressure drop (maximum 3 p.s.i.).**
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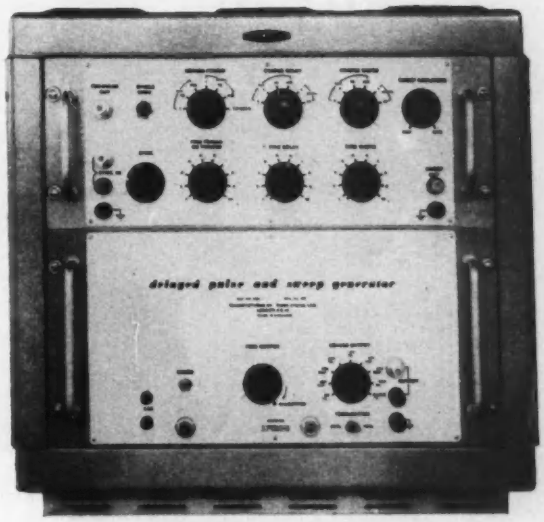

BRIEF SPECIFICATION

Period

Continuously variable from 0·9μsec to 1·05sec i.e. 0·95c/s to 1·1Mc/s. Accuracy ±5%.

Pre-pulse

40mμsec. 8V peak in 75Ω, positive going.

Main pulse

Width: Variable from 0·09μsec to 105msec ±5%.

Amplitude: Control gives 4:1 attenuation of each of four maximum outputs as follows:

5V max in	75Ω	rise time 10mμsec
10V max in	150Ω	rise time <20mμsec
25V max in	600Ω	rise time <40mμsec
50V max in	1000Ω	rise time 50mμsec

Polarity: Positive or negative going.

Accuracy: ±2%.

Delay

Conclusion of pre-pulse to advent of main pulse, delay variable from 0·09μsec to 105msec. Accuracy ±5%.

Sweep

D.C. coupled negative going sawtooth same width and delay as main pulse.
15V peak max.

Cable pulse

Obtained from short circuited pure line.
One positive and one negative going pulse coincident with main pulse.
25mμsec wide 3V max in 75Ω, rise time <8mμsec.

Sync, trigger or single shot facilities provided.
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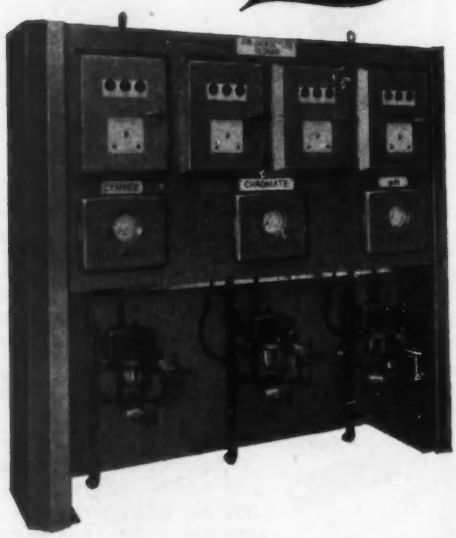
Lock INSTRUMENTATION
NUCLEAR CHEMICAL ELECTRONIC

Effluent and Trade Waste INSTRUMENTATION BY Lock



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2. IBM 1410. IBM's latest computer in the 1400 series incorporates many of the features that have made the smaller IBM 1401 so successful, plus the storage and processing capacity of larger computer systems, plus RAMAC. The I.B.M. 1410 includes:

* Up to 40,000 positions of immediate access core storage.
* 4.5 microsecond access time (more than twice as fast as the IBM 1401).
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* Up to 20 magnetic tape units. Tape units may be combinations of the IBM 7330, IBM 729 II, or IBM 729 IV.
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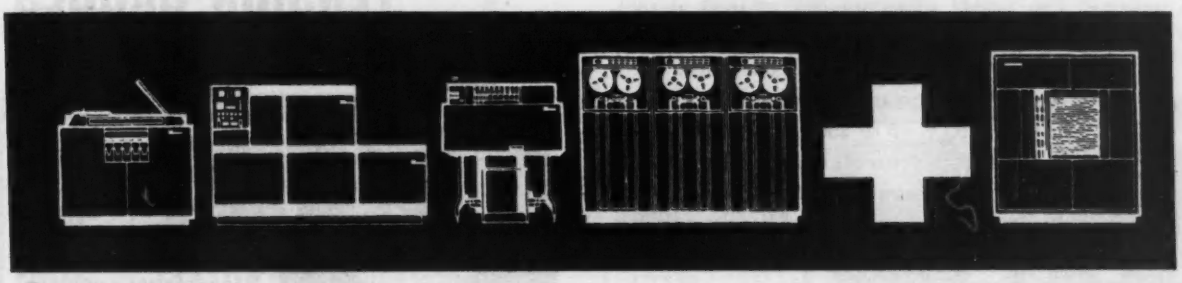

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We can supply 10 amp and 50 amp cells with maximum p.i.v. up to 400 volts ex stock, and stack assemblies of them in all the usual connections. The small losses in these modern devices permit rectification efficiencies well in excess of 99%. May we send you details and prices?

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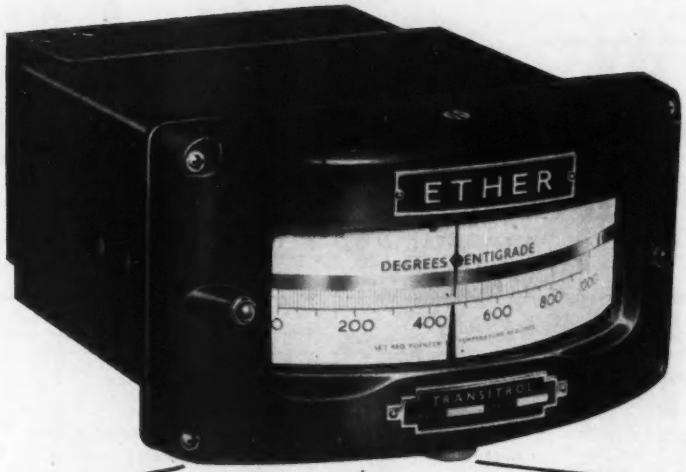

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High-temperature alarms.
Extruding and moulding machines, etc., etc.

TYPE 991:
Anticipatory

Operating:
Solenoid valves.
Motorised valves.
Contactors. Relays.
Electric Heaters.

Applications:
Extruding machines and moulding presses for plastics, rubber, etc.

Die-casting machines.

Furnaces for crystal growing.

Chemical processing.
Food packaging machinery, etc., etc.

TYPE 992:
Proportioning (stepless)

Operating:
Saturable reactors.

Applications:
Electrically-heated equipment requiring extremely accurate temperatures, e.g. plastic extruders for high-quality production.

Electric furnaces employed on research.

Electronic production, etc., etc.

TYPE 993:
Three-position (employing any combination of the preceding control systems).

Operating:
Solenoid valves.
Motorised valves.
Contactors. Relays.
Electric heaters.
Saturable reactors.

Applications:
For the independent control of sequential heating and cooling or for controlling a floating valve in:—
Salt-baths for heat-treatment of metals.
Vitreous-enamelling furnaces.
Muffle furnaces.
Crucible furnaces.
Extruding machines.
Moulding presses.
Die-casting machines, etc., etc.

TYPE 995:
Continuously-acting Proportional (with manual reset)

Operating:
Motorised proportioning valves.

Applications:
Gas-fired or oil-fired molten-metal vats.

Continuously-fed furnaces.

Lehrs.

Drying ovens and kilns, etc., etc.

TYPE 994:
Time-Temperature (employing any one of the preceding control systems).

Operating:
Solenoid valves.
Motorised valves.
Motorised proportioning valves.
Contactors. Relays.
Electric heaters.
Saturable reactors.

Applications:
For controlling the rise and fall of temperature over a given period of time in:—
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There's a quarter of a century's experience built into every one

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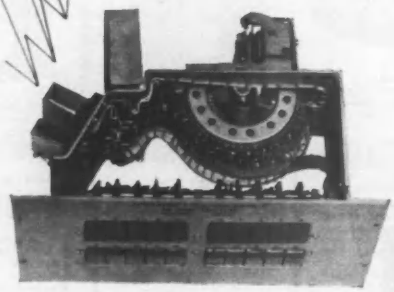
A COMPACT MODULAR ASSEMBLY
OFFERING MAXIMUM FLEXIBILITY IN
SEQUENTIAL SWITCHING SYSTEMS



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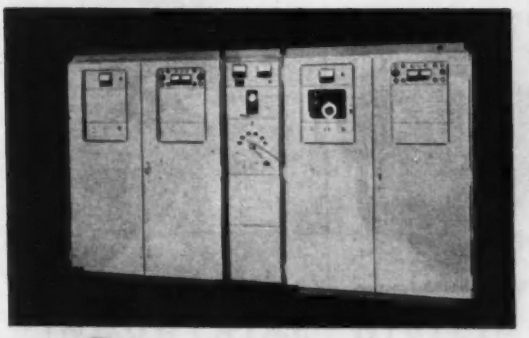

Illustrated left, is a PA 20KVA Power Amplifier; and above, the E501 'g' Control Amplifier.

*

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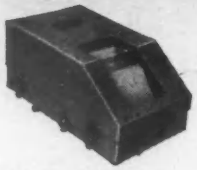
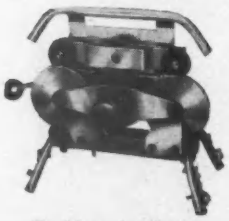


The Spark Recorder



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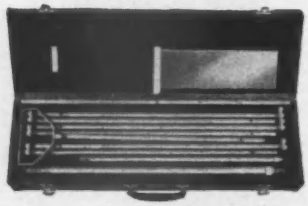
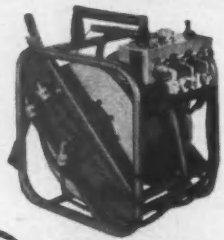


The Transit Case with legs, probes, etc.



The winch with Junction Box attached

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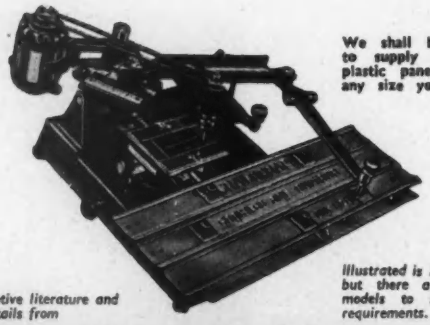

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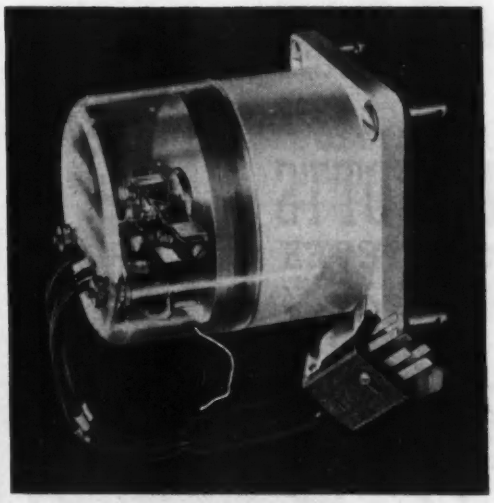

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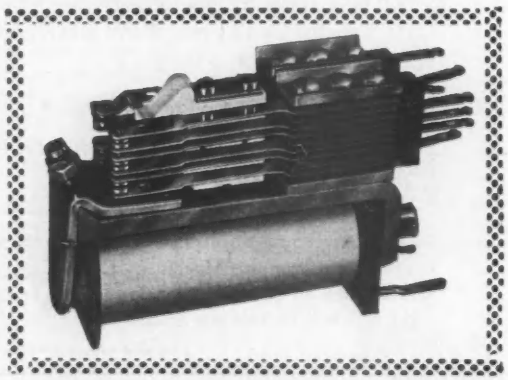

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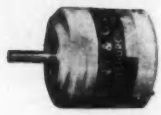

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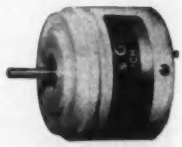

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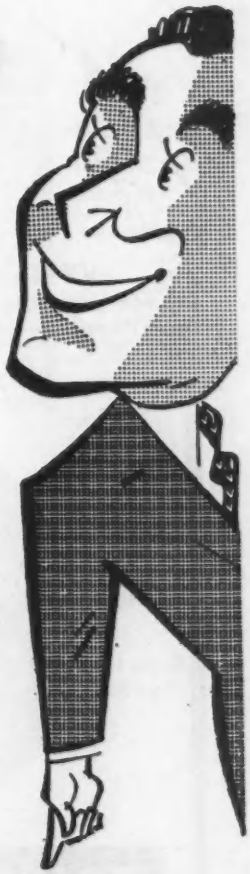

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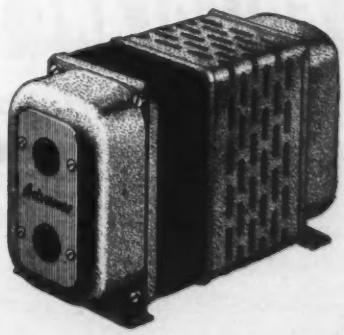

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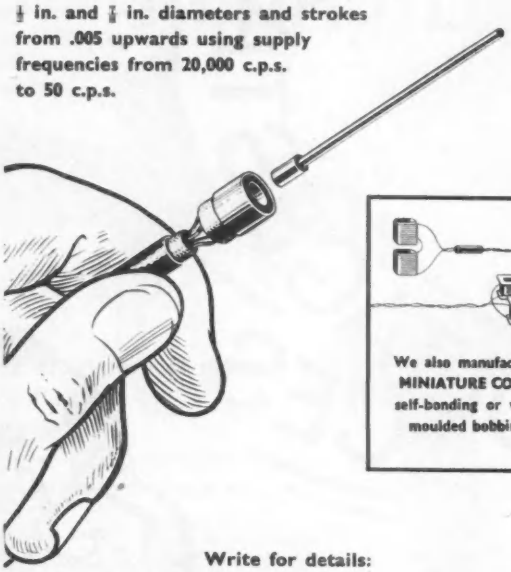

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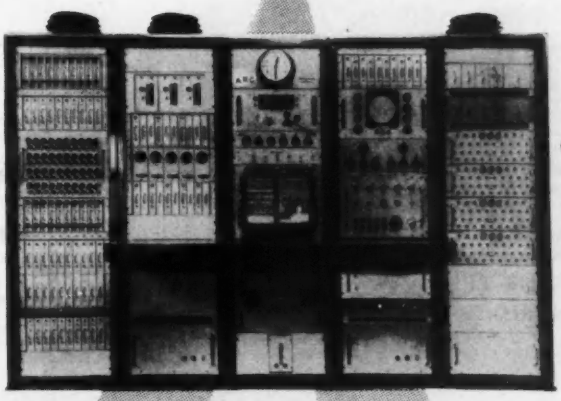

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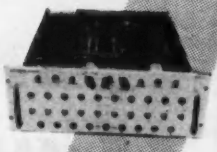

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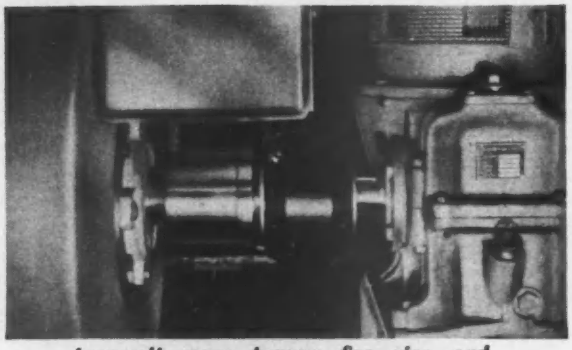

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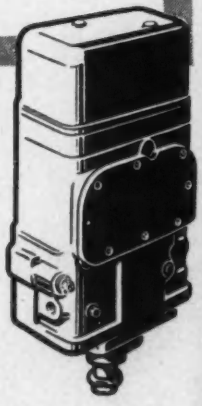

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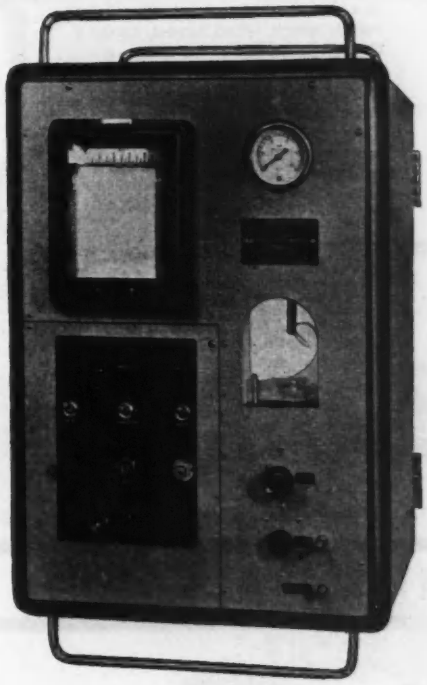

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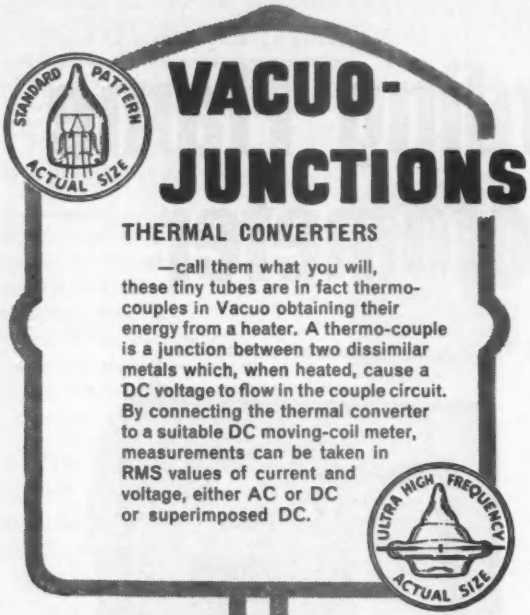
STANDARD PATTERN
ACTUAL SIZE
VACUO-
JUNCTIONS
THERMAL CONVERTERS
—call them what you will, these tiny tubes are in fact thermo-couples in Vacuo obtaining their energy from a heater. A thermo-couple is a junction between two dissimilar metals which, when heated, cause a DC voltage to flow in the couple circuit. By connecting the thermal converter to a suitable DC moving-coil meter, measurements can be taken in RMS values of current and voltage, either AC or DC or superimposed DC.
ULTRA HIGH FREQUENCY
ACTUAL SIZE

We manufacture a wide range of Vacuo-Junctions available as insulated or contact types and will be pleased to quote for your individual requirements. For our descriptive leaflet, write to:—

Best

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BEST PRODUCTS LIMITED
FELIXSTOWE · SUFFOLK
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FHP MOTORS

FRACMO MOTORS

Our very wide range includes:
A.C./D.C. Universal, Split Phase, Three Phase, Capacitor, Synchronous and Shaded Pole Motors 1/250 h.p., to 1/3 h.p., also Geared Units, 0.125 to 600 r.p.m. with Torque up to 850 lbs./ins.

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Agents: S. Birchall, 31 Malden Drive, Manton, Eccles, Manchester. *Eccles 1084*
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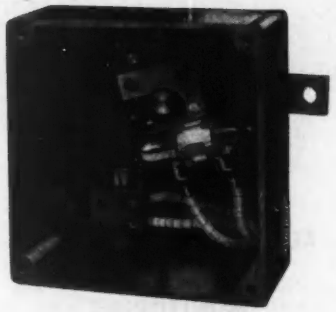
SWITCH UNITS
SWITCH RELAYS



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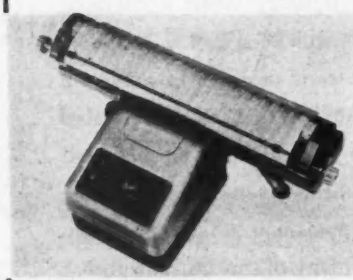
FAST DIGITAL PRINTER
FOR DATA LOGGING AND CENTRAL SURVEY



PRINTS:— 5-14 digits in parallel.
SPEED:— 3 Lines/sec.
CARRIAGE:— Max. 144 digits 31 columns.
WIDTHS:— 320 mm, 450 mm, and 620 mm.

Designed for the automatic interrogation of any type of electronic scaler or 10 position switch.

Minimum of additional circuitry required for existing equipment as printer incorporates transistorised interrogation and printing circuits with power supply.

Optionals: Black/red changeover, date, line counter, code.

We design and manufacture
COMPLETE SURVEY SYSTEMS

RADIATRON 7 SHEEN PARK, RICHMOND, SURREY
Telephone: Richmond 3285

GPS

COMPUTERS
SIMULATORS
INSTRUMENTS
CONTROL MECHANISMS

- Large & Small Analogue Computers.
- High & Low Power Amplifiers.
- Function Generators.
- Low & High Speed Servos.
- Stable Power Supplies.
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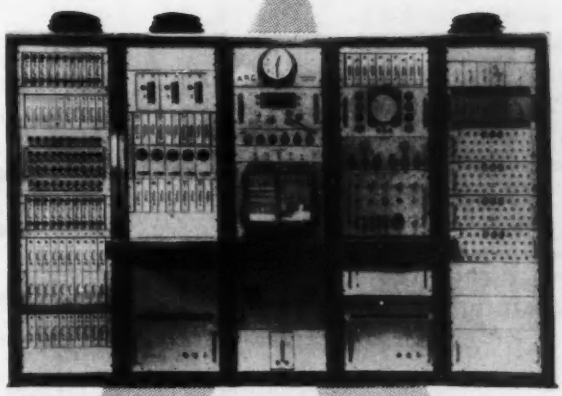
- Integrating Units.
- Limiting Units.
- Potentiometer Panels.
- High Speed Printers.
- Thermistor Air Flow Meters.
- Mercury Vapour Detector.
- Gravity Photosedimentometer.
- Centrifugal Photosedimentometer.
- Elastic Yarn Relaxation Test Equipment.



50-Amplifier G.P.S. Analogue Computer installed at Aylesbury and available for hire.

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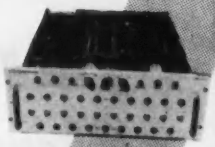
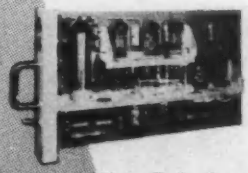
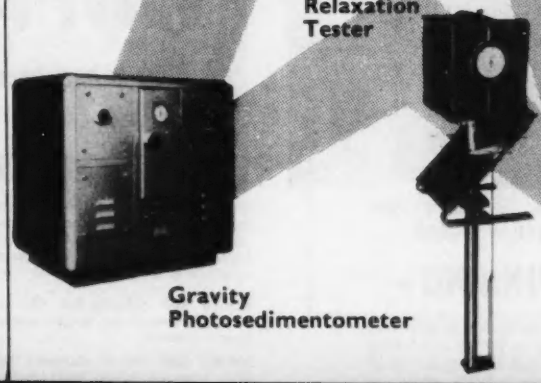


Elastic Yarn Relaxation Tester



High Gain Low Drift Amplifier.



Gravity Photosedimentometer

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SMALL PRECISION GEARS
UP TO ADMIRALTY CLASS I

NORMAL RANGE 24 TO 100 D.P.
IN ANY RECOGNISED MATERIAL

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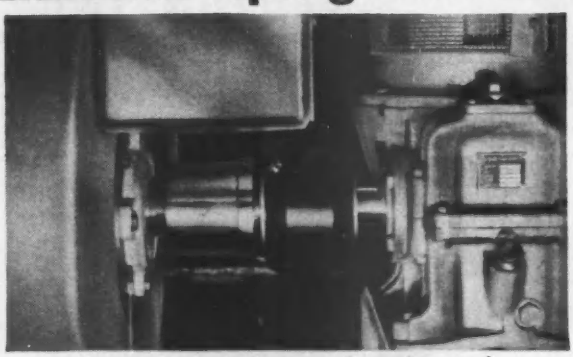
RENOLD Sprag Clutches



transmit more torque for size and weight than any other clutch

for *OVER-RUNNING—

Illustrated by this application connecting an auxiliary geared motor with the driving motor of a printing machine for starting, inching and slow speed operation. The clutch over-runs continuously when the main motor is driving.

***In one phase of a mechanical cycle the clutch transmits torque; in the other phase of the cycle the driving member comes to rest, or reduces speed, while the driven member continues to rotate.**

Write for catalogue giving details of our comprehensive range of over 70 standard sizes for over-running, indexing and instantaneous back-stopping.

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RENOLD CHAINS LIMITED
SPRAG CLUTCH UNIT
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For accuracy, ease of reading, robustness, economy and long, trouble-free life install Rototherm Thermometers, Controllers and Recorders. Specialists in bi-metallic applications.
Write for details.

Rototherm

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THE BRITISH ROTOTHERM CO. LTD.
Morton Abbey, London, S.W.19 **LIBerty 7461**
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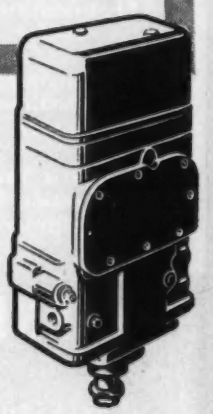
Ardleigh Governors

FOR CLOSE RELIABLE SPEED CONTROL



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SERIES 300 Suitable for most applications including generator sets, marine propulsion and diesel electric traction.

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SERIES 600 General purpose governors particularly suitable for control of A.C.—D.C. generating sets.

SERIES 700 Developed to fill the need for a small general purpose governor.

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STANDARD IRONWORKS, PORT LANE, COLCHESTER
Telephone: COLCHESTER 73209

Recording Flame Photometer

FOR THE

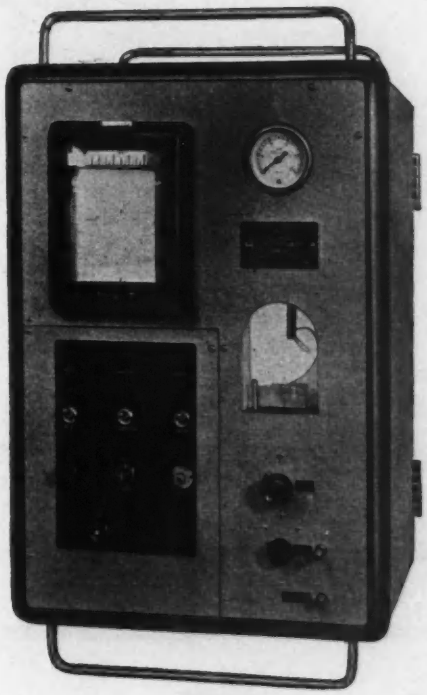
ACCURATE CONTINUOUS

MONITORING

OF

ALKALI

CONCENTRATIONS



This apparatus will prove of inestimable value in super-heated steam power stations and in all spheres of industry where continuous sampling is indicated. The "EEL" Recording Flame Photometer is designed to provide a continuous monitoring of the sodium level of sample solution drawn from a pipeline, and with slight modification can be applied to the measurement of potassium, lithium or calcium. Such is the sensitivity of this instrument that a concentration of only 0.01 ppm sodium will give *full scale deflection.*

THE "EEL" FLAME PHOTOMETER

This photo-electric instrument is designed for the accurate analysis of samples for the presence of sodium, potassium, calcium or lithium and has been tested and adopted in chemical laboratories throughout the world.

Fuller details are available from the manufacturers

EVANS ELECTROSELENIUM LTD

Sales Division : 95 St. Andrew's Works, Halstead, Essex Phone : Halstead 2461

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VACUO-JUNCTIONS

STANDARD PATTERN ACTUAL SIZE

THERMAL CONVERTERS

—call them what you will, these tiny tubes are in fact thermo-couples in Vacuo obtaining their energy from a heater. A thermo-couple is a junction between two dissimilar metals which, when heated, cause a DC voltage to flow in the couple circuit. By connecting the thermal converter to a suitable DC moving-coil meter, measurements can be taken in RMS values of current and voltage, either AC or DC or superimposed DC.

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BEST PRODUCTS LIMITED
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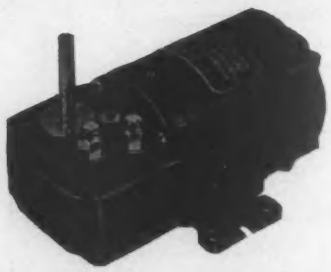

FRACMO MOTORS

Our very wide range includes:
A.C./D.C. Universal, Split Phase, Three Phase, Capacitor, Synchronous and Shaded Pole Motors 1/250 h.p., to 1/3 h.p., also Geared Units, 0.125 to 600 r.p.m. with Torque up to 850 lbs./ins.

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Agents: S. Birchall, 31 Malden Drive, Monton, Eccles, Manchester. *Eccles 1084*
Law & Plumtree, "Glenholme", Holme Road, Matlock Bath, Derbyshire. *Matlock 326*

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SWITCHES
SWITCH UNITS
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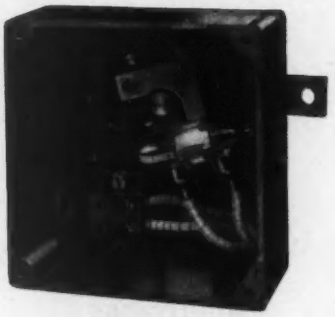

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FAST DIGITAL PRINTER
FOR DATA LOGGING AND CENTRAL SURVEY

PRINTS:— 5-14 digits in parallel.

SPEED:— 3 Lines/sec.

CARRIAGE:— Max. 144 digits 31 columns.

WIDTHS:— 320 mm, 450 mm, and 620 mm.

Designed for the automatic interrogation of any type of electronic scaler or 10 position switch.

Minimum of additional circuitry required for existing equipment as printer incorporates transistorised interrogation and printing circuits with power supply.

Optionals: Black/red changeover, date, line counter, code.

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COMPLETE SURVEY SYSTEMS

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The type MC-1 conductivity bridge is an invaluable aid to the water engineer in the laboratory or in the field, for the determination of water purity, where it may be depended upon for precise, accurate measurement and trouble free service.

The instrument is supplied complete with an ELECTRONIC SWITCHGEAR patented, non-glass conductivity measuring cell and all accessories, in a convenient hardwood carrying case. The development of low power consumption transistorised circuits, which operate from a small long life dry battery, has resulted in the production of a particularly compact and lightweight precision instrument.

Descriptive leaflet MC-1 available on request.

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ELECTROLYTIC CONDUCTIVITY MEASURING SETS, RECORDERS, CONTROLLERS AND CELLS · CONTROLS FOR LIQUID AND SOLID LEVELS · TIMING · PHOTOELECTRIC PACKAGING REGISTRATION · ETC.

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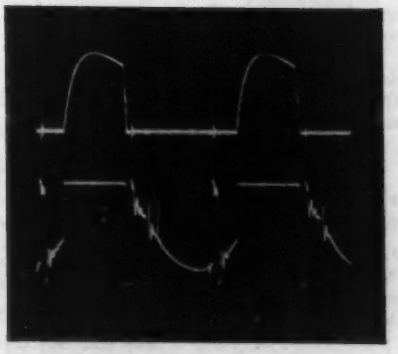

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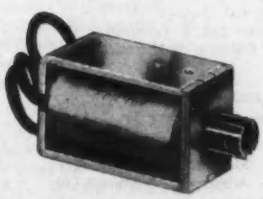

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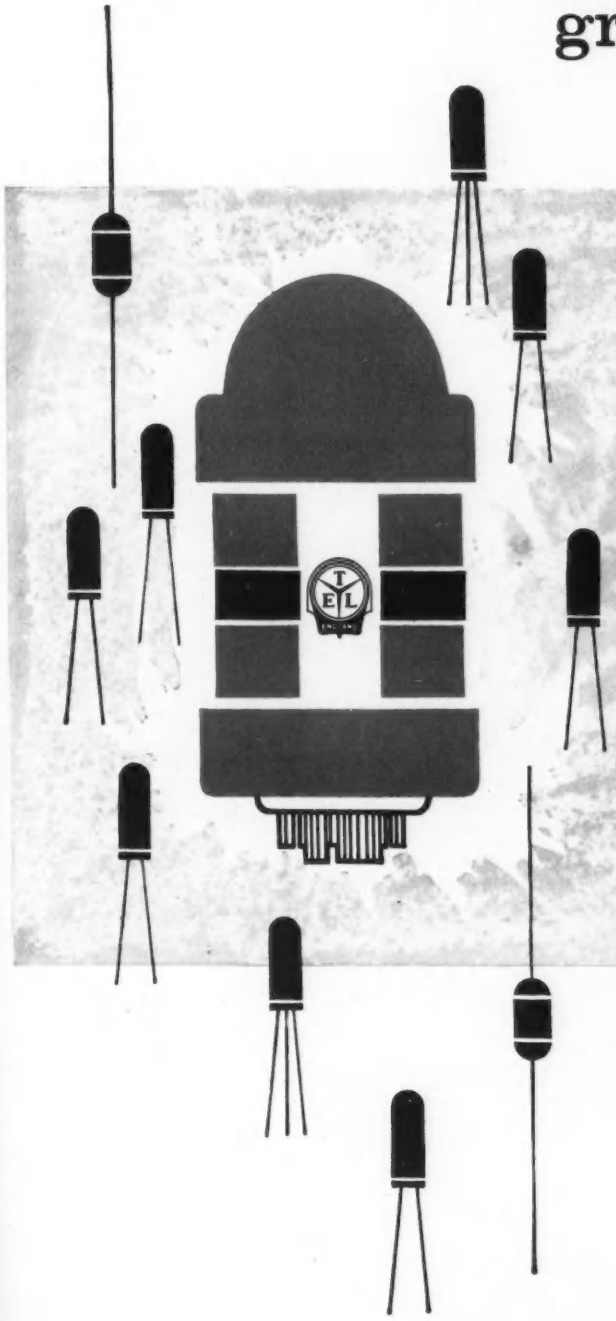

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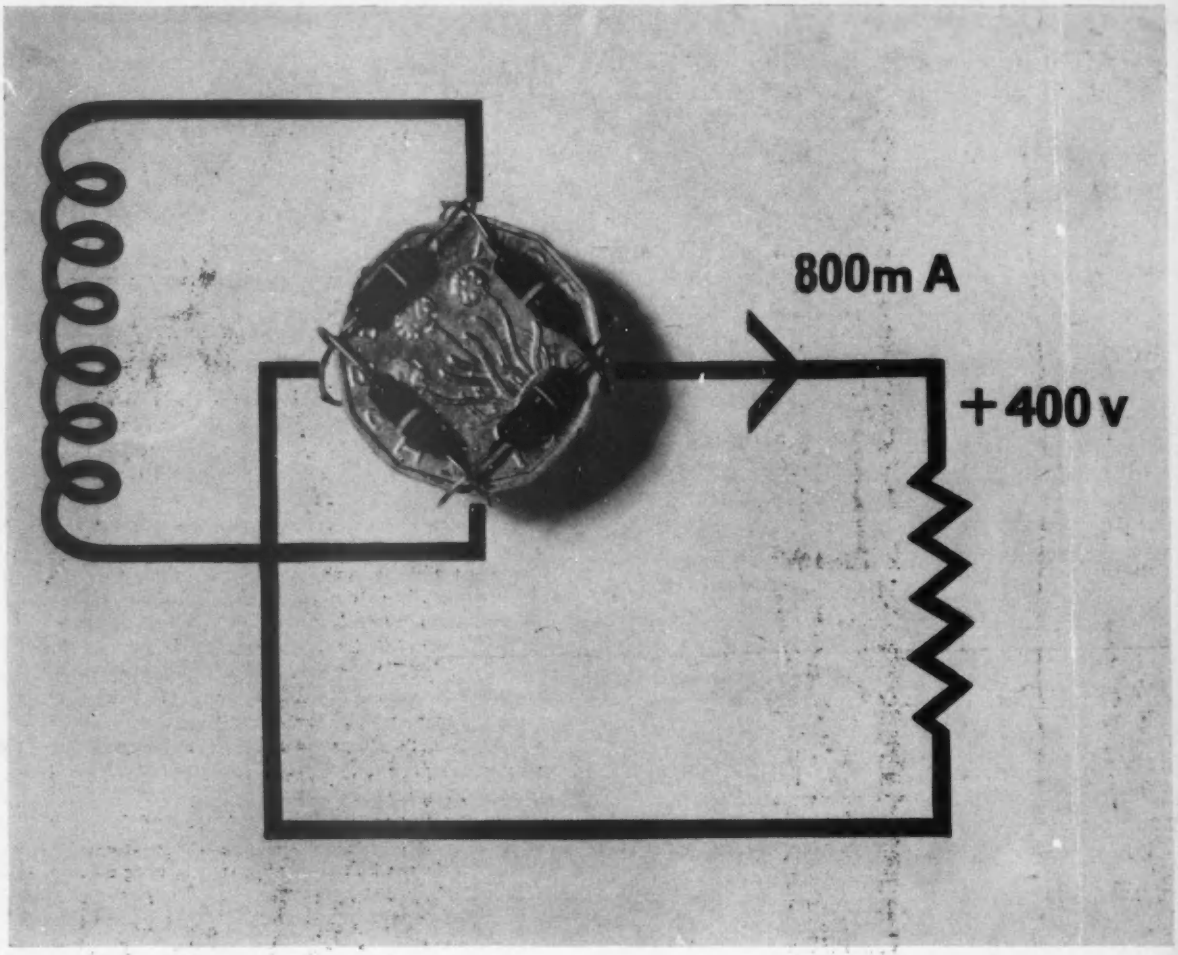

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